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Portfolio Analysis in the Context of the Concept Decision Process

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PREFACE

This document reports the work performed by the Institute for Defense Analyses for the Office of the Under Secretary of Defense, Acquisition, Technology, and Logistics (Joint Advanced Concepts) in partial fulfillment of the task entitled “Improving DoD Acquisition.”

The authors wish to thank Dr. John Hanley, Mr. Michael Fitzsimmons, and the reviewers, Dr. David Graham and Dr. Stuart Starr, for valuable comments and suggestions.

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SUMMARY

The Concept Decision (CD) process was launched by the 2006 Quadrennial Defense Review (QDR) of the Department of Defense (DoD), which states that

> Assessments of potential solutions should be informed by the acquisition community's judgment of technological feasibility and cost-per-increment of capability improvement, and by the resource community's assessment of affordability. These inputs will be provided early in the decision-making process, before significant resources are committed.

Under the direction of the Under Secretary of Defense for Acquisition, Technology and Logistics; the Director, Program Analysis and Evaluation; and the Vice Chairman of the Joint Chiefs of Staff (the Tri-Chairs), the CD process is designed to better harmonize the Department's three major decision-support processes—requirements generation, acquisition management, and resource allocation. The benefits are expected to include:

- Greater future stability of acquisition programs that have been subjected to the early CD process
- Faster development and fielding of new military systems
- More explicit consideration of potential non-materiel solutions to important capability gaps, and
- The analytic identification of programs for potential divestment to serve as sources of funding for added capabilities from within the same general mission area or portfolio.

The purpose of the Concept Decision process is to make an early decision on an affordable capability investment strategy responsive to future joint warfighter needs. The measure of success is the creation of sufficient information, in a portfolio based context, to make such investment decisions so as to yield predictable performance. Four pilot programs were nominated to develop an experiential base from which implementation guidance can be constructed. To date the CD process has focused primarily on investment in equipment – in part because the initiative has been led by the office of the Under Secretary of Defense (Acquisition, Technology and Logistics), who has been delegated decision authority on such matters. However, the basic portfolio analysis and management concept includes ***all*** elements of the defense program that contribute to military capabilities, principally equipment and force structure. The extent to which the

CD process will actually be used for making decisions on future force structure has not been resolved.

The primary purpose of this paper is to develop an approach to portfolio analysis in the CD process and to guide, in a general way, future practitioners in undertaking CD Evaluations of Alternatives (EoAs). The basic structure of such analyses is to identify zero–net-cost changes to the appropriate portfolio that would result in improved capabilities to meet specified challenges. The approach to portfolio analysis presented in this paper is as applicable to the tasks of the Institutional Reform and Governance (IR&G) Capabilities Portfolio Managers (CPMs) (another and more far-reaching initiative of the 2006 QDR, described later) as it is to the tasks of the CD EoA Study Directors, which is the main topic of this paper.

This paper explores a number of important considerations in conducting Concept Decision Evaluation of Alternatives, particularly with regard to the key process of defining and analyzing the capability portfolio relevant to the mission area. The *raison d'être* of a Concept Decision review is to address a critical capability gap that has emerged through other processes and to do so early enough so that the resulting decision can be integrated into the Department's long range budget plans without undue disruption. The normal expectation is that currently unplanned resources will be required to provide capabilities to close the gap. Future resources are almost always in tight supply. Thus, in the absence of increased total funding for DoD, there is a compelling need to identify, as a source of funds, things that are currently funded but assessed to be less critical in the future than capabilities needed to close or reduce the gap. That task ranks, along with the sound construction and analysis of gap-filling capability alternatives, among the key tasks the EoA study team must address.

This paper suggests a theoretical framework for portfolio analysis in the CD context. That approach must be tempered when it encounters the real world. The need for EOA study teams, some of them cross-service in composition, to identify through analysis a suitable source of funding from within portfolio-related programs is a difficult challenge. But unless the discipline needed to do so is exercised, the primary benefit of "portfolio management" will be lost and the decision-making process will revert to the historical practice in which the requirements community, aided and abetted by the acquisition community, identified effective ways to reduce risk by spending more money than currently planned, thus leaving to the program/budget community the task of finding funding sources for those initiatives. The result would be a less coherent overall defense

program than would be the case if each set of mission area experts maximized their own capabilities within currently planned spending. After accomplishing optimization within portfolios, a higher-level risk assessment and reallocation decision forum—such as the current DAWG (Deputy's Advisory Working Group) process—could conduct the essential cross-mission risk assessments and reallocations prior to finalizing the next Future Years Defense Program (FYDP).

Not only can the approach described in this paper benefit the ongoing four CD pilot EoAs, it also has direct applicability to the Department's larger portfolio management initiatives being pursued under the QDR-directed IR&G process. The portfolio analyses being conducted in both the CD and IR&G pilots should be examined for lessons applicable to creating a more complete and accurate "baseline" procedure to be used even more broadly throughout the Department as the portfolio management concept continues to expand.

Ultimately, the success of the CD initiative will be determined by the prevalence of acquisition programs that provide timely responses to the needs of the future U.S. combat forces. That success depends, in turn, on sound, timely analytical support to the responsible DoD decision-makers. The principles articulated in the paper are intended to further that end.

Although it was not a primary purpose of this paper to develop findings and recommendations, four recommendations have emerged from the effort:

- The two ongoing DoD portfolio management experiments, i.e. within the CD and the IR&G processes, should be harmonized. "Lessons learned" from those experiments should be assessed, documented, and shared between the two communities.
- The need for better analytical tools applicable to DoD portfolio management is evident. Starting from the "lessons learned" analysis recommended above, gaps in current analytical methodologies, tools and data should be documented and approaches to mitigating those gaps identified. Once that is accomplished, an effort to develop improved methodologies should be undertaken.
- The systems engineering process should be applied early in systems acquisition to evaluate technical and engineering risk. To avoid initiating programs prematurely, such an evaluation should become part of the basis for a decision on the next stage of development.

- The current uncertainty needs to be resolved concerning the extent to which the CD process will continue to be used:
  - Primarily for reaching decisions strictly on materiel solutions, ***or***
  - As a broader forum wherein materiel and non-materiel solutions are considered along with tradeoffs on equipment quantities and associated force structure.

I. INTRODUCTION

The Concept Decision (CD) process was launched by the 2006 Quadrennial Defense Review, which states:

> Assessments of potential solutions should be informed by the acquisition community's judgment of technological feasibility and cost-per-increment of capability improvement, and by the resource community's assessment of affordability. These inputs will be provided early in the decision-making process, before significant resources are committed.[1]

Under the direction of the Under Secretary of Defense for Acquisition, Technology and Logistics; the Director, Program Analysis and Evaluation; and the Vice Chairman of the Joint Chiefs of Staff (the Tri-Chairs), the CD process is designed to better harmonize the Department's three major decision-support processes--requirements generation, acquisition management, and resource allocation—for major acquisition and joint programs.[2] The benefits are expected to include:

- Greater future stability of acquisition programs that have been subjected to the early Concept Decision process
- Faster development and fielding of new military systems
- More explicit consideration of potential non-materiel solutions to important capability gaps, and
- The analytic identification of systems for potential divestment to serve as sources of funding for added capabilities from within the same general mission area or portfolio.

The CD purpose is to "make an early decision on an affordable capability investment strategy responsive to joint warfighter needs."[3] The measure of success is the creation of sufficient information, in a portfolio based context, to make an early and affordable capability investment decision yielding predictable performance. Four pilot programs are under way to develop an experiential base from which implementation guidance can be constructed.

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1 Quadrennial Defense Review Report, February 6, 2006, p. 67.

2 There will likely be a similar process at the DoD Component level for non-major acquisition, Component-specific programs. We use the term "(CD) decision-making body" in this paper for the Tri-Chair or the Component-level counterpart, as appropriate.

3 October 30, 2006 Tri-Chair meeting.

The primary purpose of this paper is to develop an approach to portfolio analysis in the CD process and to guide, in a general way, future practitioners in undertaking CD Evaluations of Alternatives (EoAs). The basic structure of the analyses is to identify zero–net-cost changes to the appropriate portfolio that would result in improved capabilities to meet specific challenges. The approach to portfolio analysis presented in this paper are applicable to both the tasks of the Institutional Reform and Governance (IR&G) Capabilities Portfolio Managers (CPMs) (another, more far-reaching initiative of the 2006 QDR, described later) and the tasks of the CD EoA Study Directors, which is the main topic of this paper.

Although the general format of the paper is that of an annotated briefing, on some pages more extensive remarks are included that go beyond material covered in the briefing charts. The appendices also provide supporting material in considerably more detail.

II. BACKGROUND AND PORTFOLIO ANALYSIS IN THE CD CONTEXT

As reflected in Figure 1, portfolio analysis is part of the Evaluation of Alternatives, which replaces the Functional Solutions Analysis (FSA) and the Analysis of Alternatives (AoA) of the process that existed prior to the CD initiative. (The components of those processes and their relationship with the CD process are discussed in more detail in Chapter III, Sections B and D).

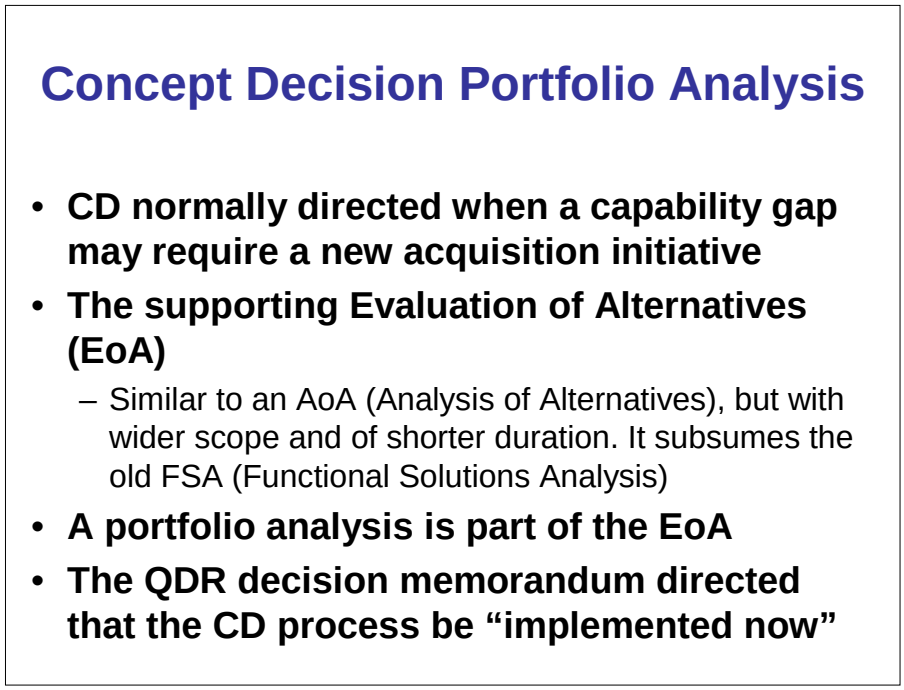

Figure 1. Concept Decision Portfolio Analysis

A. ORIGINS OF PORTFOLIO MANAGEMENT

Before discussing the particular application of portfolio analysis techniques in the CD/EoA context, we will begin with a short discussion of the origins and current application of portfolio management and analysis outside the DoD (largely in private industry).

The graph in Figure 2 illustrates "classical" investment portfolio theory, in which an investment mix is determined to provide the greatest return consistent with an

acceptable level of risk.[4] The "efficient frontier" represents a set of portfolios that provide the greatest expected return for a fixed level of risk, or conversely, the least risk for a fixed expected return.[5]

Although this concept may not apply, in a mathematical sense, to portfolios in the Department of Defense, it has validity at the conceptual level. The analog might be stated as follows: for a fixed level of capability needed (analogous to the "expected return" in the MPT), DoD should seek portfolio mixes of capabilities that provide the desired aggregate capability at minimum risk. Alternatively, one could fix the level of risk to an acceptable level and seek portfolio mixes of capabilities that would close the gap at minimum cost.

The basic concept can be generalized to represent "efficient frontier" choices for such variables as performance versus cost or risk versus cost.

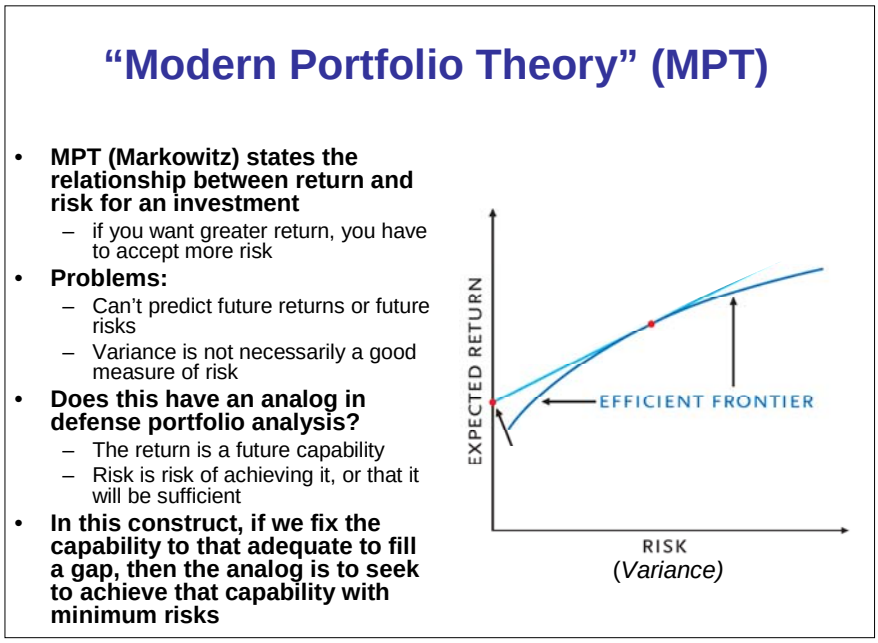

Figure 2. "Modern Portfolio Theory" and its Applicability to Portfolio Analysis in the DoD Context

B. PORTFOLIO MANAGEMENT AND ANALYSIS IN THE PRIVATE SECTOR

Figure 3 outlines the concept of portfolio management and analysis as used in private industry today. In some industries, this is a routine part of strategic planning

[4] Harry Markowitz won a Nobel Prize in economics in 1990 for work that included this theory.

[5] Risk here means the probability that an unfavorable outcome will occur.

within each product line, or business area. A recent Government Accountability Office (GAO) report [6] described the process used by five prominent companies in the private sector as follows:

> To ensure [achieving] a balanced mix of executable development programs, the successful commercial companies …use a disciplined and integrated approach to prioritize market needs and allocate resources. This approach, known as portfolio management, requires companies to view each of their investments from an enterprise level as contributing to the collective whole, rather than as independent and unrelated. … [A] portfolio management approach begins with an enterprise-level identification and definition of market opportunities and then prioritization of those opportunities within resource constraints.

A key feature of the private industry processes described by GAO is the winnowing down of investment choices as more information about the potential payoffs, risks, and costs become available to decision-makers, who must make tradeoffs within limited resources to achieve adequate returns with acceptable risks. Success is critical to the very future survival of the company.

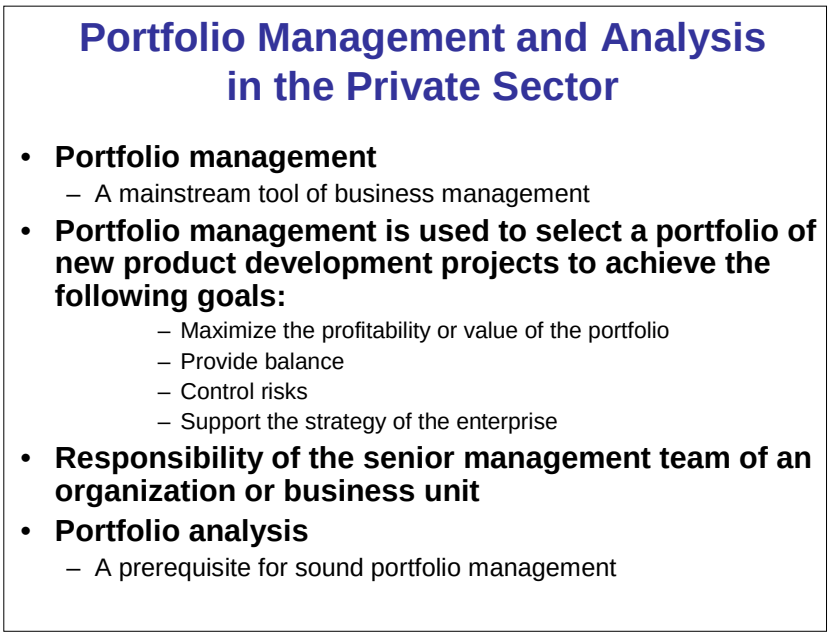

Figure 3. Portfolio Management and Analysis in the Private Sector

While the GAO report emphasizes that portfolio management should be done at the enterprise level, that is very difficult at DoD, as it is in very large diversified companies. Although difficult, such tradeoffs must and will be made, either explicitly or

[6] *Best Practices: An Integrated Portfolio Management Approach to Weapon System Invests Count Improve DoD's Acquisition Outcomes*, GAO-07-388, March 2007.

implicitly, at the DoD enterprise level. Our concern in the CD context, however, is not enterprise-level portfolio management,[7] but rather more limited portfolios covering a capability area.

Companies invest in R&D as part of their investment portfolios for several reasons: to improve products to maintain competitive posture; to reduce risks by providing alternative products and product components; and to achieve break-throughs with the potential for great opportunities in the market place if successful. Historically, the Defense Department has hedged in similar ways by having the Defense Advanced Research Projects Agency (DARPA) and some other organizations invest in high-risk, high-potential-payoff activities. It has done less well within major acquisition programs of record,[8] often short-changing risk-reduction initiatives, as well as failing to establish the reserves that will predictably be needed.[9]

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7 The domain of the IR&G portfolios mentioned above.

8 The phrase "program of record" is used to mean a DoD activity, or group of activities, that has funding in the Future Years Defense Program (FYDP).

9 By "predictable" we mean that, out of a given set of programs, some are likely to require management reserves. It can't usually be predicted which particular program will need it. Unfortunately, maintaining management reserves on any consistent basis appears to be "a bridge too far" for DoD. Such funds are simply too attractive as "bill-payers" when short-term budgetary shortfalls have to be met.

III. PORTFOLIO MANAGEMENT AND ANALYSIS IN THE CD PROCESS

The Department's renewed emphasis on Capabilities Based Planning is intended to increase attention to the "output" of the Department's investments, rather than the input "stove pipes." Interest in managing by output, "mission areas" or "capability areas," has a long history in defense management theory, but has yet to be fully harmonized with the concomitant need to structure budgetary inputs. The CD initiative, with its use of capability portfolios, is a major step in this management improvement process.

A. PORTFOLIOS

Figure 4 defines "portfolio" within the CD process.

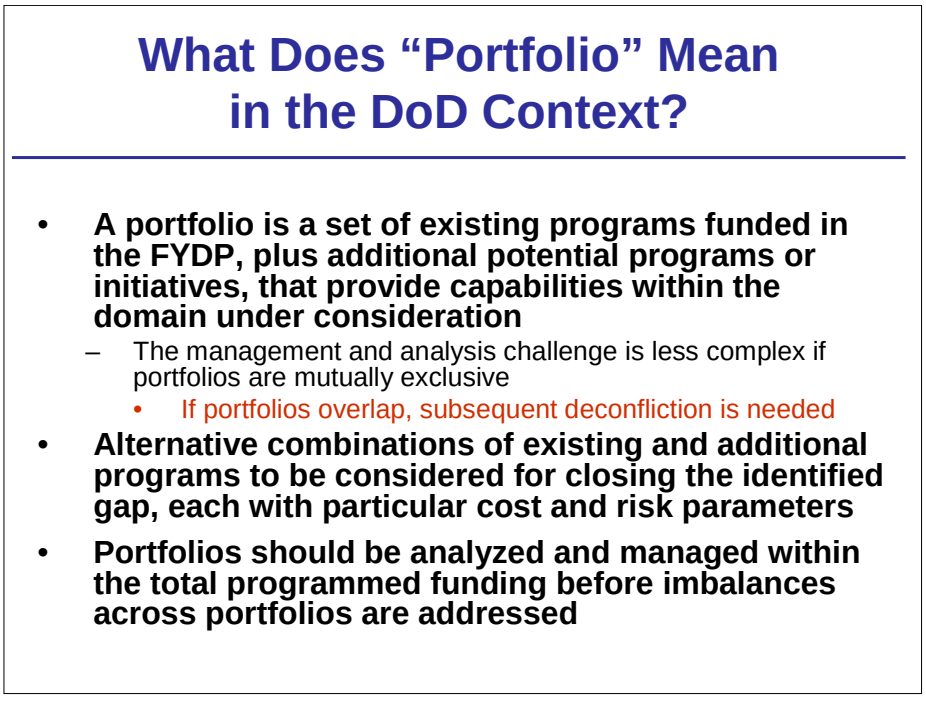

Figure 4. "Portfolios" in the DoD Context

Within the CD process, a portfolio is defined as a set of materiel and non-materiel programs that correspond to a capability.[10] The specific programmatic content of the portfolio to be analyzed should ideally be defined in the EoA Study Plan, if not provided in the EoA Guidance. If it is not provided, an early priority of the EoA study team should be to establish the appropriate capability portfolio. Even if provided, the portfolio would need careful review for completeness and appropriateness of the programs included. At this early stage of utilization of the portfolio management concept within the Department, it is unrealistic to expect exact identification of 100 percent of the programs that logically belong to such portfolios, but it is important that the study teams be able to start their work promptly with the content of the vast majority of the portfolio's programs clearly defined.

B. CAPABILITY GAPS

Figure 5 outlines the concept of "capability gaps" within the CD context. It is essential that the analyses of capability gaps begin with national military goals and objectives as prescribed in the President's National Security Strategy, the Secretary of Defense's National Defense Strategy, the Chairman's National Military Strategy, and the Secretary of Defense's Guidance for the Development of the Force.[11]

[10] The relationship to the Joint Capability Areas (under development in a task being led by the Joint Staff/J-7 under direction from the Deputy Secretary of Defense) will be discussed subsequently.

[11] Formerly the Strategic Planning Guidance and the Contingency Planning Guidance

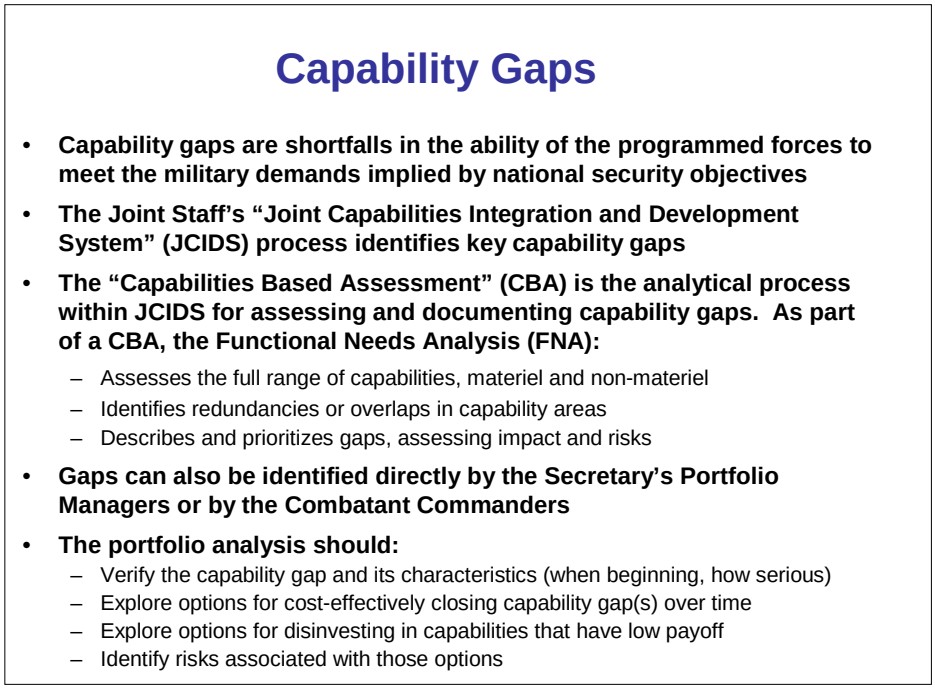

Figure 5. Capability Gaps

The Joint Staff is responsible for translating national security objectives into military requirements. The Joint Staff instituted the Joint Capabilities Integration and Development System (JCIDS) process to support the Joint Requirements Oversight Council (JROC) in translating strategic priorities into military operational needs or requirements to meet those priorities. The objective of JCIDS is to support the JROC in "identifying, assessing, and prioritizing joint military capability needs."[12]

The key component of JCIDS in defining capability gaps is the Capabilities Based Assessment (CBA) process, and more particularly within the CBA, the Functional Needs Analysis (FNA). The FNA assesses the capabilities of the programmed force to meet military objectives (as defined by a preceding Functional Area Analysis).[13] Based on the FNA, a Joint Capabilities Document (JCD) is developed to document the capability gaps. A Functional Needs Assessment should, if done properly, set the stage for the portfolio analysis part of the CD process. CJCS Manual 3170.01C defines the FNA as follows:

> The FNA assesses the capabilities of the current and programmed warfighting systems to meet the relevant military objectives of the scenarios chosen in the FAA using doctrinal approaches. Using the standards and evaluation criteria

[12] CJCS Instruction 3170.01F, "Joint Capabilities Integration and Development System," May 2007.

[13] CJCS Manual 3170.01C, "Operation of the Joint Capabilities Integration and Development System," May 1, 2007. Those readers not familiar with JCIDS may wish to consult these documents, since it is beyond scope of this report to provide a full explanation of the JCIDS processes.

> described the FAA, the FNA assesses whether or not an inability to achieve a desired effect (a capability gap) exists. The FNA also identifies any capability areas that may have overlaps or redundancies.

The CJCS manual also states that

> The FNA must then assess the impact of the capability gaps in terms of the risk to mission (ability to achieve the objectives of the scenario), the risk to force (the potential losses due to the capability gap)...The FNA should offer a prioritization of gaps that is directly linked to priorities in the strategic guidance, but the document must publish sufficient information to expose how these priorities were developed…It must also completely document the significant driving factors behind the recommended priorities to give senior leaders the information they need to make adjustments.

The final component of the CBA process is the Functional Solutions Analysis. After validation of the JCD by the JROC, an FSA may be conducted to identify viable solutions to the capability gap, including both materiel and non-materiel alternatives. At the completion of the FSA, a sponsoring DoD Component offers materiel solutions in an Initial Capabilities Document (ICD). Non-materiel solutions are addressed with a doctrine, organization, training, material leadership and education, personnel, and facilities (DOTMLPF) Change Request (DCR).

The Joint Staff's CBA process has identified a significant number of gaps, but few if any redundancies, thus rendering that process of limited value in balancing ends and means. It is the goal of the CD EoA process to identify such balances, at least at the portfolio/mission area level. By combining these efforts, a large number of potential alternative DOTMLPF solutions for closing a capability gap can be screened (as part of the FSA-like analyses) to determine a small group of the most promising alternatives to be refined in more detail (as part of the AoA-like efforts). This approach is designed to supplant the extensive, time consuming and costly sequential FSA and AoA analytical efforts that have frequently been performed in the past.

C. THE TRADE SPACE

Figure 6 describes the concept of "trade space" as it relates to the CD process. Trades **within** the portfolios are the result of *analytical comparisons of the (time-dependent) operational effectiveness, suitability, risk, and life-cycle cost of alternatives that satisfy established capability needs*. The EoA team will be asked to identify sources within the portfolio that could provide the resources needed to implement an alternative with minimal adverse impact. The decision-making body may decide that the identified sources are not acceptable. In those instances, they will recommend looking for resources

in other portfolios, using risk assessment and allocation techniques. More generally, it is the Department's policy to require portfolio managers to demonstrate that the contents of their portfolios have been thoroughly "scrubbed" before consideration will be given to tapping other capability portfolios to obtain needed resources.

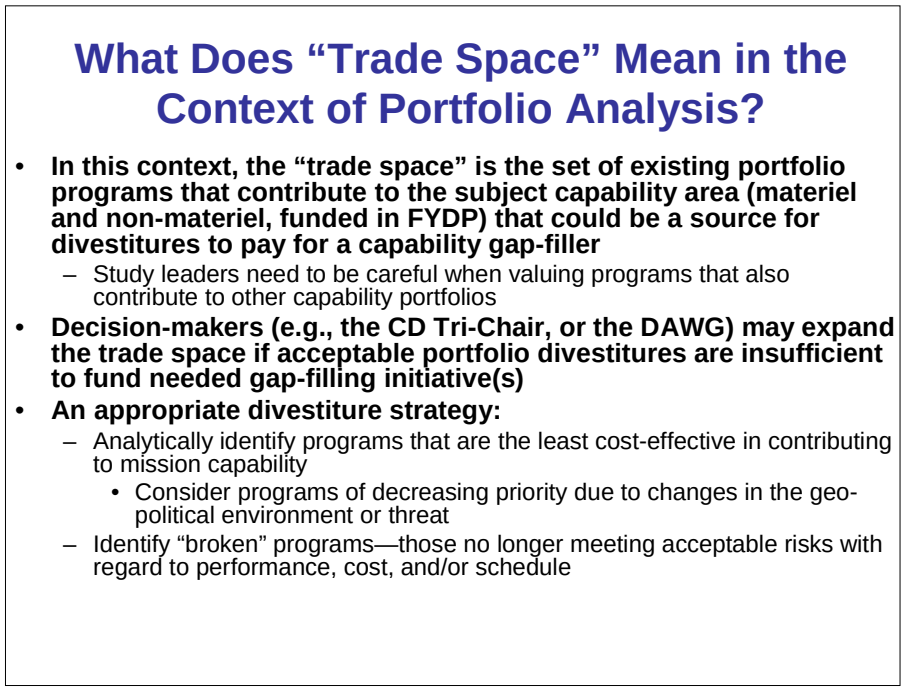

Figure 6. Defining the Trade Space for Portfolio Analysis

D. AoAs AND EoAs

The EoA of the CD process is intended to be a streamlined analytic methodology to support the specific capability development decision at hand.[14] The EoA creates an analytical linkage between the requirements and the acquisition processes, and when combined with the trade space analysis described above, it extends that linkage to the Department's resource allocation process (i.e., the planning, programming. and budgeting system). The EoA combines the objectives of the FSA component of the JCIDS, with the objectives of the Analysis of Alternatives, which is now routinely conducted at the front end of the acquisition management process as defined by Department of Defense Instruction (DoDI) 5000.2. Another difference is that an EoA should consider a far broader range of potential solutions, including, in particular, non-materiel solutions,

[14] Traditional AoAs typically took two years or more to complete, costing several million dollars. An EoA, on the other hand, should be completed in less than a year, at considerably lower cost.

whereas AoAs usually considered only narrowly-defined materiel solutions designed to justify or refine a "pre-anointed" choice.

According to the Defense Acquisition Guidebook,[15]

> An AoA is an analytical comparison of the operational effectiveness, suitability, and life-cycle cost of alternatives that satisfy established capability needs. Initially, the AoA process typically explores numerous conceptual solutions with the goal of identifying the most promising options ….

The output of the CD process may be one or more formal acquisition programs that could serve as candidates for near-term Milestones A, B or C,[16] depending on how mature the program is. In any case, the EoA should serve as the AoA required by DoDI 5000.2. If the appropriate milestone for the program is Milestone A, then the CD review will normally serve as the Milestone A review. For such programs, an AoA that updates the EoA will likely be required prior to Milestone B. Likewise, for a program going directly to Milestone B in the near term, an updating AoA will likely be required before Milestone C.

E. THE FOUR PILOTS

Soon after the start of the CD initiative a set of four pilot programs were nominated to serve as vehicles to explore and refine the CD process, particularly with regard to EoAs. Figure 7 describes the four pilots. The following extract from EoA study guidance document for the Joint Light Tactical Vehicle pilot explains the rationale:

> The expected pilot outcome will help address corporate DoD issues and provide potential benefits to the concept decision process. Specifically, JLTV is expected to help identify how the Department addresses broad product line needs which cut across Service, joint force and the Tactical Wheeled Vehicle capability portfolio lines. The EoA could also provide a potential concept decision benefit of a better-informed and earlier investment decision at Milestone B.

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15 Available at the Defense Acquisition University website, http://akss.dau.mil/dag/.

16 Appendix B, Section 2, summarizes the key aspects of the DoD acquisition management process as it affects CD.

Figure 7. The Concept Decision Pilots

Two of the four pilot EoAs are completed—JLTM and JSRG. The IAMD EoA is near completion. The Global Strike Raid EoA was delayed for many months due to issues regarding access to classified programs.

An extensive set of "lessons learned" was developed by the CD Working Group in August 2007. Although that compilation is a useful starting point, it was constructed from suggestions offered by members of the group, not a systematic, comparative review of the EoAs by qualified analysts. The result is, by and large, a collection of unexamined generalities. Thus, there is still a need for a more rigorous and focused review of the four pilot EoA studies from an analytical perspective by a single entity with the appropriate expertise.

IV. AN APPROACH TO PORTFOLIO ANALYSIS FOR CONCEPT DECISIONS

Figures 8-11 outlines a more formal approach to performing portfolio analysis in the CD context. Appendix A expresses the basic steps outlined in Figures 8-11 as a formal mathematical model.

A. DEFINE THE PORTFOLIO

Figure 8 outlines the steps required to define the portfolio. The first step is to identify all (or at least most) of the programs that provide capabilities in the portfolio and which are funded in the Future Years Defense Program (FYDP), since those are the only programs to which the Department has officially allocated resources (i.e. the programs of record). It is likely to be the case that many of the programs contributing capabilities to the portfolio will also provide capabilities to other portfolios. There are also likely to be programs that support, directly or indirectly, the primary programs within the portfolio. In each case, it is essential to document where programs to be included within the portfolio contribute to other portfolios. When the identified programs have distinct Program Elements (PE) in the FYDP, then it is easy to determine the funding flow for the program. However, many times programs are rolled up with other programs in a FYDP PE.[17] In that case, it is necessary to request the FYDP funding streams from the Component in whose budget the program resides. Once all programs have been identified, the next step is to rank-order them by the level of capability provided (determined, quantitatively if possible, by analysis). This rank-ordering serves two purposes—it identifies the major contributors to the current capability (the top programs) and programs to be considered for tradeoff (the bottom of the list).

Ideally, sensitivity analysis will be conducted on the major contributors to the capability area. If the FYDP funds the last 10 percent of the equipment set for an important contributor, those funds may be relatively less productive than similar funding for the initial tranche of a new contributor whose overall importance, when fully fielded, might still not reach the top of the priority list. Understanding the capability

[17] See Appendix D for more on this point.

contributions of the programs in the portfolio and the sensitivity of their contributions at various funding levels will be of substantial value in moving to the next step.

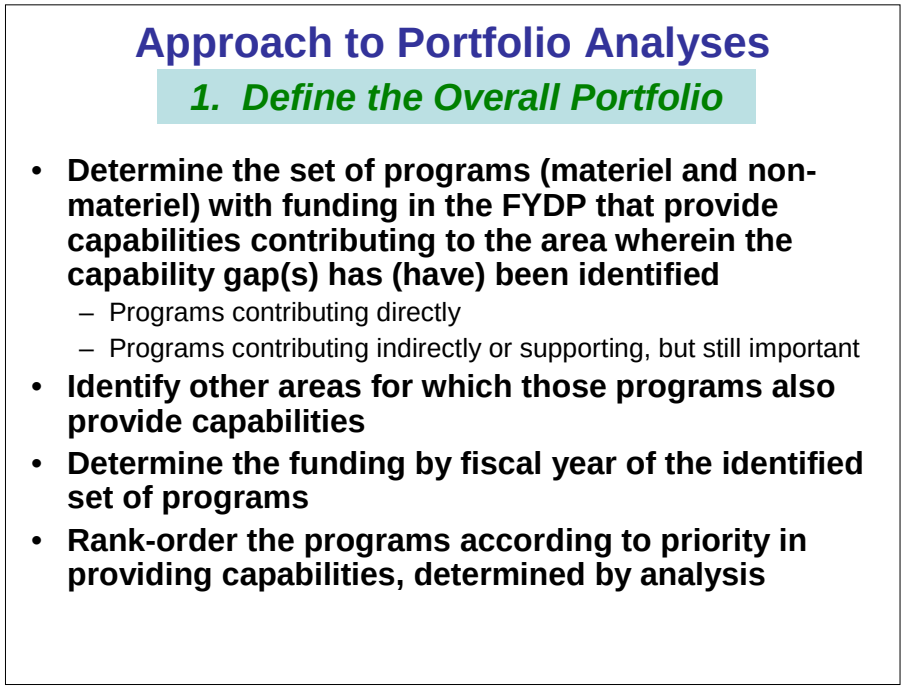

Figure 8. Approach to Portfolio Analyses—Defining the Portfolio

B. DEFINE THE POTENTIAL SOLUTION SETS

Figure 9 continues with steps to define a set of alternatives that appear to be capable of closing the capability gap. In doing so, it is important to cast as wide a net as possible, considering solutions ranging from modifications to existing programs to technology initiatives and non-materiel solutions (changes to DOT_LPF—i.e. DOTMLPF without the "M," such as increased force structure using currently programmed equipment). The time dimension is also an important consideration. A capability gap could occur at any time—near-, mid- or long-term—and may change over time. For example as a new threat weapon system is projected to emerge in the future, it starts with an initial operational capability then to a full operational capability. So the EoA analyst must take into account the time dimension in formulating solution sets.

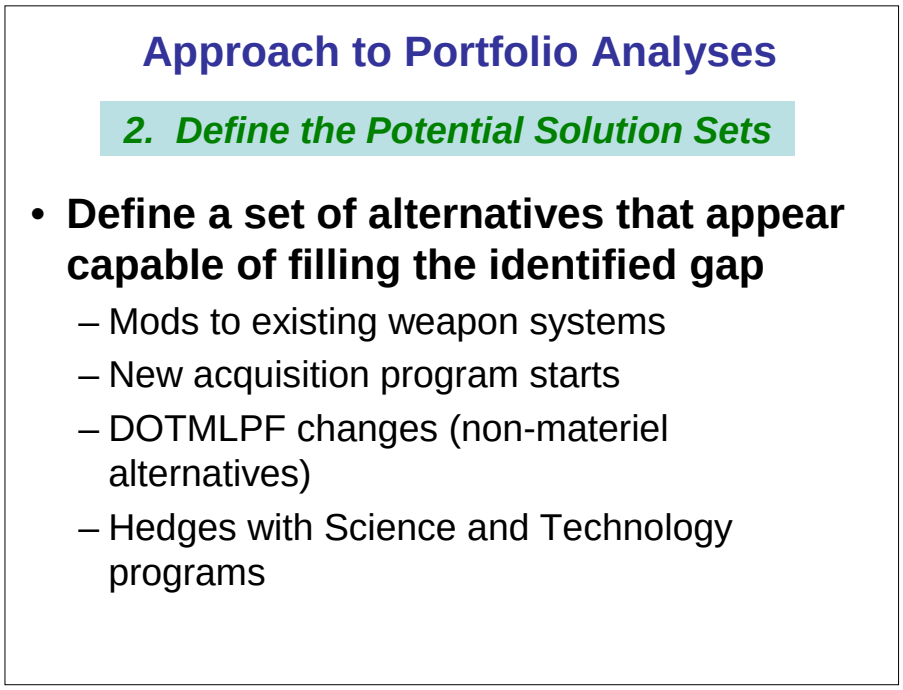

Figure 9. Approach to Portfolio Analyses—Defining the Potential Solution Sets

C. TRADEOFF ANALYSIS

Figure 10 outlines the steps for the tradeoff analysis. The EoA context provides more rationales for identifying a program as an offset candidate (in addition to those discussed in the Section III.C). Does the program have an impact on the gaps that generated the concerns leading to the CD? If not, would its termination cause other gaps? If so, are those gaps of as much concern as the ones that are the basis of the CD? Put another way, where do we want to accept risk, and how much? Negative answers to these questions could lead to placing a program in the trade space. This does not necessarily mean that the program will ultimately be offered up, but only that it should be subject to more in-depth analysis.

Programs that no longer seem to offer good returns on DoD's investment are also good trade-space candidates. There could be a number of reasons for putting a program in that category. For example, the program may be encountering so many difficulties (e.g., with testing) that the risk of successful completion is quite high. Or, the program could be perfectly healthy, but changing international situations and threat evolution may

call into doubt whether the program is still needed.[18] Even if such analysis has been conducted in other venues (which is seldom), it is very likely to require updating.

This analytic identification of viable trade space candidates is an *essential* objective of the portfolio analysis as part of the EoA.

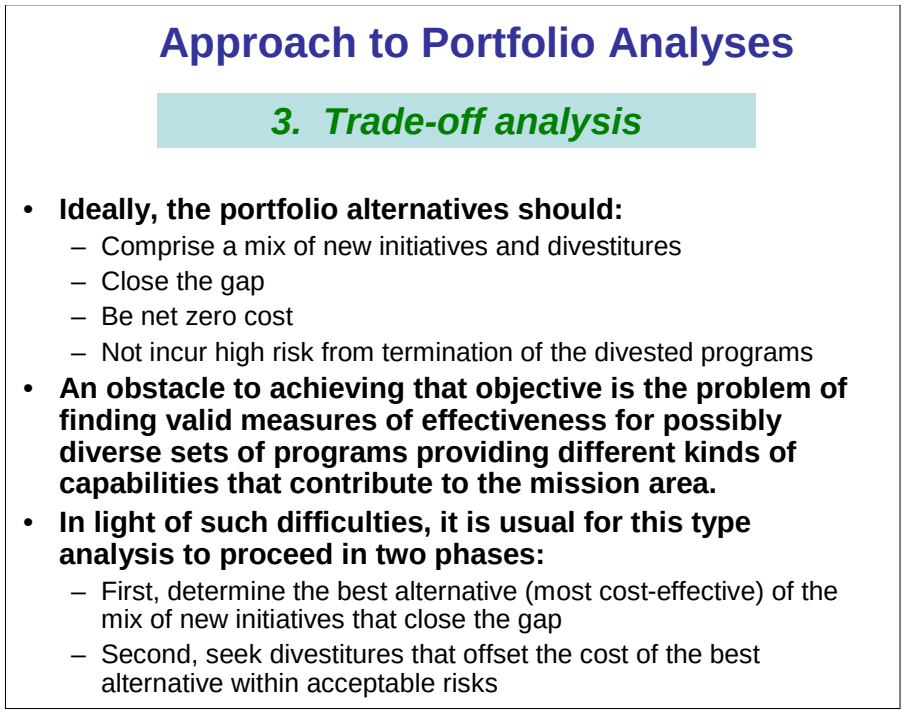

Figure 10. Approach to Portfolio Analyses—Trade-off Analysis

D. ASSESS RISKS

Figure 11 outlines some important areas of risk related to the CD process. While risk considerations are mentioned throughout this paper, this section focuses on risks that should be addressed formally in an EoA, to include ways to control or mitigate the identified risks.

[18] Or put more subtly, the program may still fill a need, but at too high a cost in relation to the benefit (for example, the need can be met with more cost-effective alternatives, or a risk can be accepted in meeting the need).

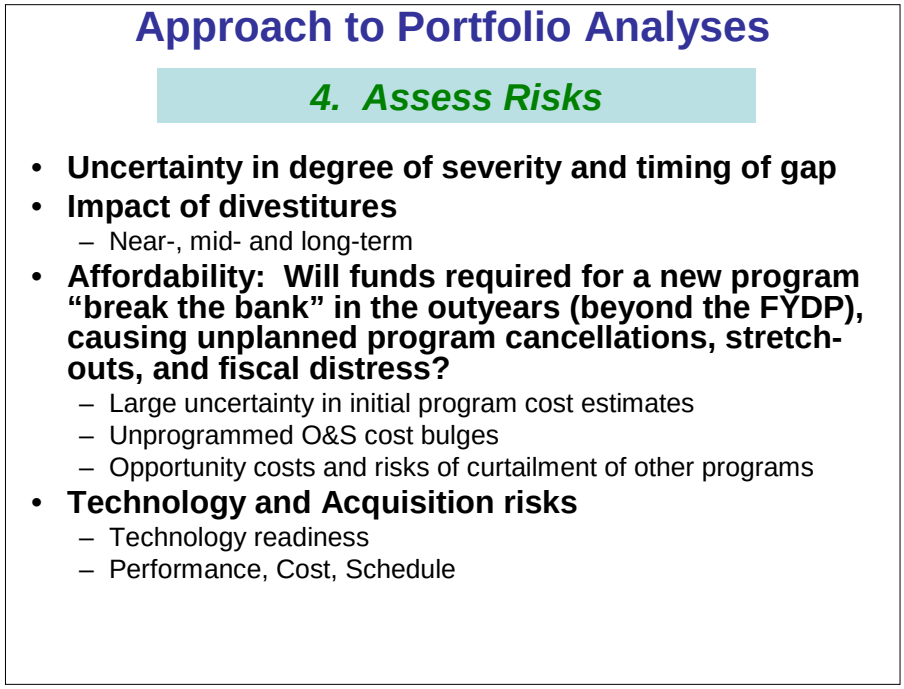

Figure 11. Approach to Portfolio Analyses—Assessing Risks

1. Risks in Defining the Gap

In many, if not most, cases the capability gap will be a projected one, not a current one. When that is the case, there will be doubt about both the extent of the gap and the timing of it. Numerous historical examples illustrate that future threats frequently do not materialize as projected. This risk might be mitigated by taking partial steps to increase preparedness to respond more vigorously if the projection turned out to be accurate—usually by pursuing a research program within the Science and Technology (S&T) budget.

2. Risks associated with divestitures

In order to be credible, it is imperative that the EoA provide a strong rationale (backed by analysis where possible) for why nominated divestitures can be taken. As part of that argument, the risks associated with the divestiture must be explored and explained to the decision-making body.

3. Affordability risk

The approach outlined in this section is the ideal. It assumes that the solutions that are capable of filling the gap can be funded with available offsets (and implicitly seeks the least damaging such offsets that will accomplish that end—see Appendix A for an

explicit formulation). In the real world, however, it may not be possible to execute the ideal plan. If, for example, the solutions are too expensive relative to the available offsets, the trade-off analysis will not converge to a net-zero-cost result. In that case, an alternative formulation might be considered:

1. Determine the total resources that can be made available from acceptable divestitures
2. Determine the (time-dependent) *extent* to which the gap can be closed with the funds available
3. Evaluate the (time-dependent) risks of not fully closing the capability gap

The decision-makers would then have a choice of nominating a larger set of programs to be included in the search for offsets or accepting the risk of not fully closing the projected gap. In consideration of the risks in assessing the capability gap, such a decision could reflect a strategy of "take modest steps now and evaluate the situation again in the future to see if more is really going to be needed." Cost risks also give rise to affordability issues; approaches to mitigating cost risks are discussed in the section below on cost considerations. In some cases it is likely that a major emerging gap will not be able to be reasonably closed with acceptable risk by trading only programs lying within a narrowly-defined portfolio area. To the extent that such trades will need to be made across several portfolios it is likely to fall outside the purview of the CD process and be handled within the traditional program review structure in which decisions are made by the Deputy Secretary. This issue is discussed in more detail in Section VI.

4. Technological Risks

For many CDs, technological risk will be a major consideration, and technology risk reduction measures should be at the top of the list of programmatic options for the decision-making body. A full discussion of technological maturity in conjunction with the CD process is included as Appendix B. The rest of this section is a summary of Appendix B.

To accomplish CD objectives through one or more prospective acquisition programs, technical risk must be adequately addressed in order to achieve program stability and predictable outcomes. Since technical risk policy is written for the current acquisition management process, it will need to be adapted to the new CD process. The best practices for doing so are a function of the type of materiel investment decision being recommended by a CD.

The EoA should assess the advancement degree of difficulty and the technical suitability for application for every area of technical risk. The results should be used to eliminate alternatives where the technological risk is too high and to determine the appropriate entry point into the acquisition framework for the remainder. While the EoA process itself may be sufficient to determine that an alternative is ready to enter the acquisition management framework at Milestone A, greater technical knowledge obtained from more refined technical analysis will be necessary before going any further. Such analyses should be used to validate the EoA results before seeking a Milestone B or C approval.

Implementing an effective approach to monitoring technology maturity in an EoA will help shift the focus of acquisition management from the System Development and Demonstration phase to the period prior to the formally defined "acquisition management" phase, when broad options are still available and can be aligned to close capability gaps.

5. Acquisition Risks

Acquisition risks are normally characterized in terms of the three inter-related parameters of cost, schedule, and performance. The GAO studies cited in Appendix B provide strong evidence that acquisition risks can be significantly reduced by rigorous application of existing technology readiness policy. Programs that started with Technology Readiness Level 6 ("system/subsystem model or prototype demonstration in a relevant environment") averaged "only" 18.8% development cost growth, while programs that started with less mature technologies averaged 34.6% development cost growth.

The second important factor in reducing acquisition risks, especially in cost and schedule, is maintaining stable requirements. The CD process carries the promise that, through early and thorough analysis of requirements, a greater degree of stability of performance requirements can be maintained throughout the acquisition program.

E. ANALYTICAL TOOLS FOR EoAs

From an analytical perspective, the problem presented by an EoA is not unique within the realm of defense analysis. Thus there are existing tools that should be applicable. This study did not conduct a thorough review of the available tools with an assessment of their applicability to EoAs. Such an effort would be a major undertaking, well beyond scope of the current study. However, three methodologies that came to light

as noteworthy in potential applicability to EoAs will be discussed in this section. In addition, since AoAs (and their predecessor, Cost and Operational Effectiveness Analyses (COEAs)) have been undertaken by DoD for a number of years (at least 30), there is a rich knowledge base on methodologies, tools, and lessons learned from those analyses. Although AoAs, by nature, are more narrowly focused than what is envisioned for EoAs, the analytical principles are very similar. The Office of Aerospace Studies, Air Force Materiel Command, at Kirtland Air Force Base maintains a database of AoA studies that covers all the Military Services. They have also published a useful guide for conducting AoAs.[19]

Three methodologies more specifically tailored for use in EoAs are discussed below.

1. The RAND Corporation Methodologies

Paul K. Davis, of the RAND Corporation, has for many years been at the forefront of defense analysis from a capabilities standpoint. In fact, his seminal work led to the adoption of capabilities based planning by DoD at the beginning of the current Administration. Davis and his colleagues at RAND have developed a family of tools of varying levels of complexity to assist capabilities based analyses and analysis of portfolios, to include EoAs. Those methods have been documented in a recent RAND paper,[20] and are only briefly discussed here. The methodology comprises two models based in Microsoft Excel®. The first is the Building Blocks to Composite Options Tool (BCOT). It accepts inputs of assessments of portfolio components ("building blocks") effectiveness and cost, then displays a scatter diagram of cost versus effectiveness, in order to identify the "efficient frontier" for the portfolio choices. This technique facilitates tradeoff analysis because the less cost-effective components of the portfolio will appear well below the efficient frontier in the display. (Caution must be exercised, though, because realistically, it is unlikely that any one measure of effectiveness will be able to adequately represent overall capabilities. Under another measure of effectiveness, the system in question may be near the efficient frontier.)

The second method is the Portfolio Analysis Tool (PAT), which displays composite "stoplight charts" for subsets of portfolio options. This method produces a "spanning set" of scenarios that test military capabilities. The distinguishing feature of

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[19] *Analysis Handbook--A Guide for Performing Analysis Studies: For Analysis of Alternatives or Functional Solution Analyses*, Office of Aerospace Studies, Air Force Materiel Command, July 2004.

[20] Paul K. Davis, Russell D. Shaver, and Justin Beck, *Portfolio Analysis Methods for Assessing Capability Options*, RAND, 2007.

PAT is the ability to "drill down" to determine what parameters drive the color of the "stoplight" entry. The drill-down can span several levels.

While these methodologies appear useful, the problem lies in the difficulties in determining the basic cost and effectiveness values needed as inputs. The methodologies are basically ways to aggregate and display the results of lower-level analyses of system effectiveness and costs. (RAND has, of course, developed numerous analytical tools for assessing system effectiveness, to include campaign-level assessments. But it is well beyond our scope to discuss them here.)

2. The Mitre Corporation PALMA Tool

Like RAND, The Mitre Corporation has a rich history of developing analytical tools and performing analytical assessments that are relevant to the type of analysis required for EoAs. The Portfolio Analysis Machine Tool (PALMA®) is "a computer program that helps decision-makers to select the best portfolio (combination) of investments from a set of potential investment options."[21] The tool is based on a mission tree structure, wherein a "strategy-to-task" tree is defined at several levels. Missions are decomposed into sub-missions, then further decomposed into subordinate missions, functions and tasks. At the lowest level (referred to as a "leaf node") data for the forces and systems that provide relevant capabilities are defined in terms of effectiveness and cost (derived externally). PALMA provides an assessment of which investment options should be funded to achieve the desired goals for the task. Like the RAND PAT, the displays are in terms of stoplight charts. The performance at each node in the hierarchy is specified by a number from 1 to 100, representing value judgments by subject-matter experts made at the leaf nodes. Performance at higher levels are computed as weighted averages of the scores at the contributing lower levels based on heuristic "importance" percentage weights (again specified by subject-matter experts). The numerical ranges are translated into red-yellow-green-blue color codes for display purposes. By changing the mix of investment options, the performance at the leaf nodes will change, and those changes will "bubble up" to changes at the mid and top levels. Thus the user can determine a mix of investment options that provide a satisfactory assessment at the mission level. To assist the user, the tool can display efficient frontier charts of cost versus effectiveness to highlight which investment choices provide the most effectiveness benefit for a particular investment level. The least cost-effective systems will lie far away

[21] Richard A. Moynihan, *Investment Analysis using the Portfolio Analysis Machine (PALMA® Too)l*, The Mitre Corporation, July 2005.

from the efficient frontier, which facilitates their identification for tradeoff analysis. The displays facilitate exploratory analysis by allowing the user to include or exclude an investment option with a simple mouse click. The user may also specify linkages among investment options, e.g., "if you want to include investment option A you must also include investment option B (but not conversely)."

PALMA is capable of including a large number of investment options ("100 or more") through the use of search methods based on genetic algorithms or integer programming. A version of the model is also available allowing time-phasing (multi-year) of investment options and budgets.

PALMA is similar to the RAND methodology, but there are differences. For example, PAT does not compute a weighted score for the top-level assessment from sub-tier assessment. Instead, it simply assigns the lowest score from the sub-tier to the next level. So if four sub-tiers are rated "green, green, yellow, red," the next higher tier would be rated "red." (There is an implicit assumption in the PALMA method that the numerical scopes can be meaningfully combined in linear combinations—i.e., a score of 20 is twice as good as a score of 10—whereas it is not clear that the subject matter experts from which such scores originated had such an assumption in mind.)

3. The Mitre Corporation Matrix Mapping Tool

The Matrix Mapping Tool (MMT) was developed for OUSD(AT&L) and Joint Staff/J-8

> to facilitate cross organization coordination and reuse in support of capabilities based planning, analysis, and acquisition. The MMT is a database with supporting software that documents relationships between warfighting activities, the UJTL,[22] systems, ACTDs,[23] roadmaps, and capability areas. It allows for a common set of reusable data to support portfolio management (functional, operational), analysis of capability gaps, and other studies where it is necessary to understand the relationships across the dimensions listed above.[24]

This tool should be of particular value to EoA study groups because of its ability to display a wealth of the pertinent information about acquisition programs and how they link to capability areas. In fact, it was used effectively in the IAMD EoA. The tool provides web links to sites containing more detailed information. For example, MMT

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22 Universal Joint Task List.

23 Advanced Concept Technology Demonstrations.

24 Judith Dahmann, Mitre Corporation; Kristen Baldwin, OUSD(AT&L)/Defense Systems; Ajay Choudhary, Fary Eiserman, Jason Femino, Gary Stutts, *Matrix Mapping Tool (MMT)*, Raytheon Virtual Technology Corporation (undated).

has a linkage to the Joint Forces Command's Joint Capabilities Mapping Environment, which contains detailed information at the systems engineering level.

V. COST CONSIDERATIONS

A. COST UNCERTAINTY

Cost is always a key consideration in any decision regarding the allocation of scare resources, and significant levels of uncertainty are typically associated with cost estimates of future capabilities. The cost uncertainties are substantially higher, however, for capabilities most likely to be considered in the CD process, because proposals for a new capability to close a gap projected for 10-15 years in the future can be expected to involve new technologies applied and integrated in new ways. The term in current usage to describe this process is "rough order of magnitude" (ROM) costing.[25] In other words there will be some large, but generally unspecified, level of uncertainty in a cost estimate. In particular, the alternatives under consideration in a CD review could have very different levels of uncertainty in their cost estimates. If an alternative with very high cost uncertainty (say, factor of two or more) is selected, it may be desirable to begin with a program to reduce the uncertainty in both cost and performance (which in fact go hand in hand).

Cost uncertainty further complicates the issue of when resources for a proposed new capability should actually be set aside in formal programs and plans. How much of a "program wedge" (if any) should be established in the FYDP for such systems? And at what point should future funding be allocated? To program funds before the technologies for a new system are proven may induce turbulence in the projected out year resources available for other programs.

One approach to this problem is one that was popular during the 1990s, known as "cost as an independent variable (CAIV)." [26] While the terminology is somewhat obscure (particularly to non-engineers), the concept is sound. The idea is to decide through an analysis of all claims on future resources, balanced against their potential payoffs, how much of the future resources can be allocated reasonably to a new capability, as a function of time. The subsequent development of the capability must be constrained by

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[25] Many using this term seem unaware of its traditional meaning—an order of magnitude literally means a factor of ten.

[26] A related concept is "Design to Cost," but that approach is normally considered at the system design level, rather than in the resource programming environment.

that resource allocation.[27] If after further development and analysis, it is determined that the allocated resources are not adequate for the successful fielding of the preferred solution, a decision must be made to either reduce the costs (and presumably also the capability) or allocate more resources (with attendant opportunity costs and risks). The discipline imposed by this approach may be of particular value in CDs.

B. THE PROBLEM OF TIME HORIZONS

A potentially critical problem that is very likely to arise in an EoA is identifying divestitures that will free up funding in the time period needed. We refer to this problem as the time-horizon issue, which is described in Figure 12.

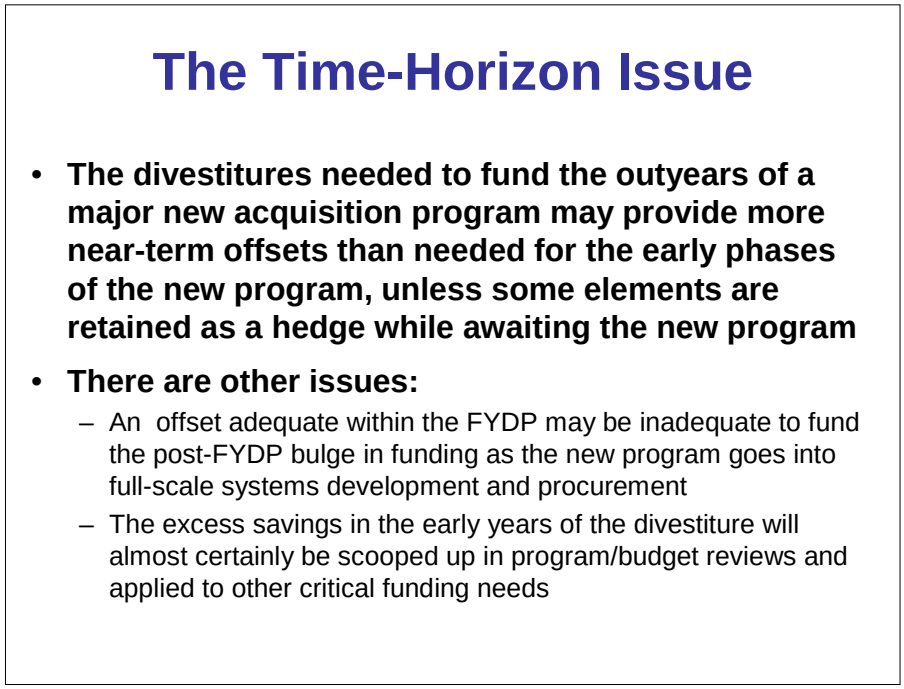

Figure 12. Timing of Funding Needs and Divesture Benefits

In the "classical" case of a new system concept, the early stages of the program will only require low levels of funding—e.g., for technology development and maturation, and proof of concept testing. Assuming success, the funding needs will likely increase over time, most dramatically after Milestone B. The need will likely step up again by a factor of two or more as Milestone C is passed. This will likely be many years into the future for major acquisition programs—in most cases beyond the FYDP. The time-phasing of divestitures to match such a profile is challenging. If the divestiture

[27] The CAIV concept as articulated in the current 5000.1 and the Defense Acquisition Guidebook fails to emphasize this key point.

is a deployed system, once it is identified as a lower priority, it is subject to near-term cancellation, which may be more than adequate to cover the initial funding requirements of the new program. Excess funds would be quickly commandeered for other purposes, so when the new CD program reaches Milestone B, the funds from the divestiture may no longer be available.

Often an existing program will provide adequate capability for the near term, but a future threat or circumstance indicates that at some point in the future, its capabilities will be inadequate (thus the gap). A new program would then be needed to replace the old one. It could take 10 or more years to develop, produce, and deploy a new capability, so the old system must be retained until the new one is deployed in sufficient capacity to counter the threat. And offsets from elimination of the old program will rarely be sufficient to cover the cost of the new capability for many years, if ever.

The time horizon problem is illustrated in Figures 13 and 14 below. Figure 13 illustrates a potential future capability gap—a new threat that is expected to be deployed starting in 2019. By 2022, the threat will exceed the current U.S. capability, creating a growing capability gap. A new system must be developed to fill that gap and Figure 13 illustrates a plausible funding profile. The existing systems must be retained to meet current requirements, but they might be reduced in quantity somewhat, since in this illustration the current capability exceeds the threat. As seen in Figure 14, initial research, development, test and evaluation (RDT&E) funding for the new start is low and can be offset by partial divestiture of the current system. However, to be able to cover the projected future gap, funding for the new capability will ramp up for systems development and procurement in four or five years. But no more divestitures can be taken to offset that need because the threat still must be countered. Thus a substantial funding gap develops in the mid- and far-term.

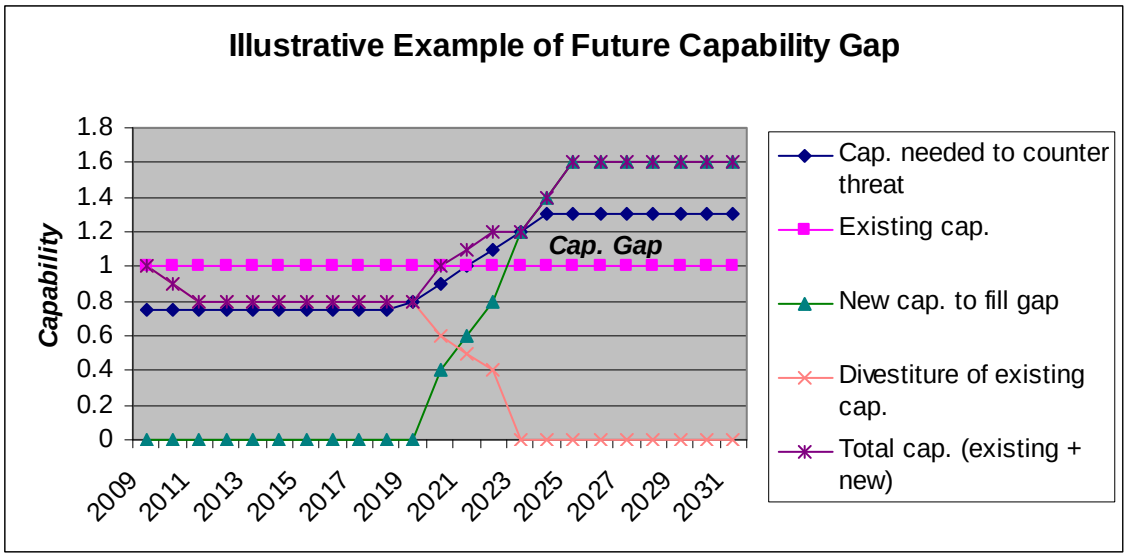

Figure 13. Illustrative Example of Providing Resources to Fund a Future Capability Gap

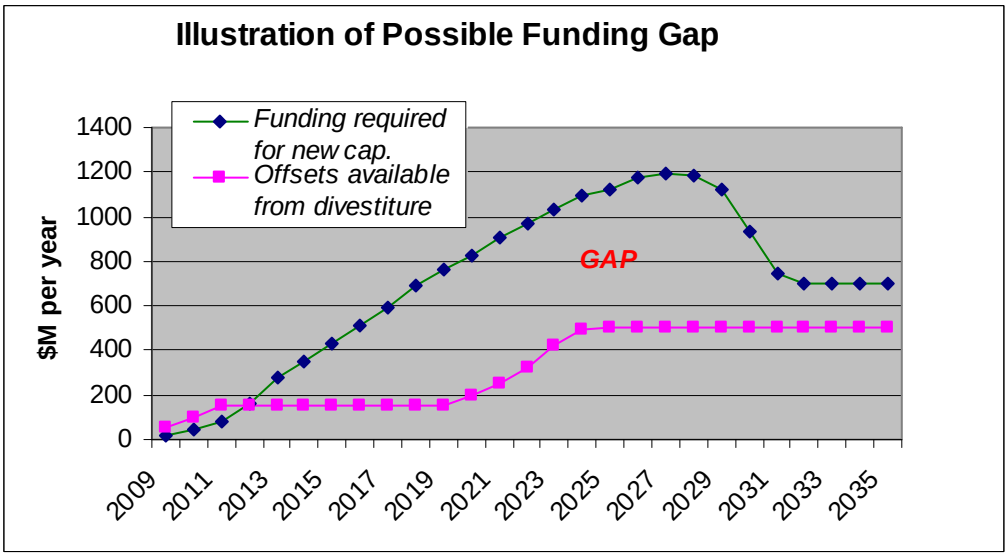

Figure 14. Illustration of Possible Funding Gap

This example is simplistic, of course, but not unrealistic. In reality, there will likely be other programs in the portfolio than can be decremented to free up funding. However, for a major new start, it is not realistic to expect that *enough* offsets within a portfolio can be found to fully fund the new capability through systems development and procurement.[28] Thus, it can be expected that offsets *outside* the portfolio will be needed.

[28] The average funding required for systems development and procurement for programs requiring Selected Acquisition Reports (SARs) over the 1995-2005 time period was $14B.

It is important to identify the likely need to make such choices at the CD point, even if they are not required immediately.

When such choices have to be made is an important parameter as well. That is the point at which (1) the future need is established beyond reasonable doubt; (2) sufficiently accurate estimates of the amount and timing of future funding become available; and (3) there is a high level of certainty that an acquisition program can be executed within acceptable risks in technology development, cost, schedule, and performance. These conditions will not necessarily be met all at once. Even if condition (1) is established, systems development should not commence until technological readiness is demonstrated. The level of risks that is acceptable will depend on the criticality of filling the capability gap. But no matter how critical the gap, experience has demonstrated that it is unwise to launch systems development and procurement before risks are fully understood. Operational work-arounds or strategy changes may be necessary in the interim.

VI. RELATIONSHIP WITH OTHER DEPARTMENTAL PROCESSES

This section discusses the relationship of the CD process to other Departmental processes, both existing and in development. These include the IR&G process and the Joint Capability Area process (both in development) and several processes within the planning, program, and budgeting system. This discussion covers processes at the Departmental level only. There will be analogous interfaces at the DoD Component level.

A. INSTITUTIONAL REFORM AND GOVERNANCE

Institutional Reform and Governance (IR&G) is another management initiative that was recommended by the most recent QDR. That initiative is much more far-reaching in scope than the CD initiative, and in fact, when broadly interpreted it encompasses the CD process. The interrelationship with the CD process is summarized in Figure 15. In a March 2007 memorandum, the Deputy Secretary of Defense outlined an implementation procedure for IR&G. The overall process is described in Appendix C, where the impact of the implementation memo on the CD process is discussed in detail. The memo establishes six "Actions to Critical Path" (ACPs) for IR&G implementation, which are listed in Figure 16. Several of the ACPs relate to portfolio analysis in support of the CD process. Certainly, one of the major thrusts of the IR&G initiative is make far greater use of portfolio contexts in DoD management.[29]

[29] As this paper was being completed, a draft DoD Directive, Subject: Capability Portfolio Management, was circulated.

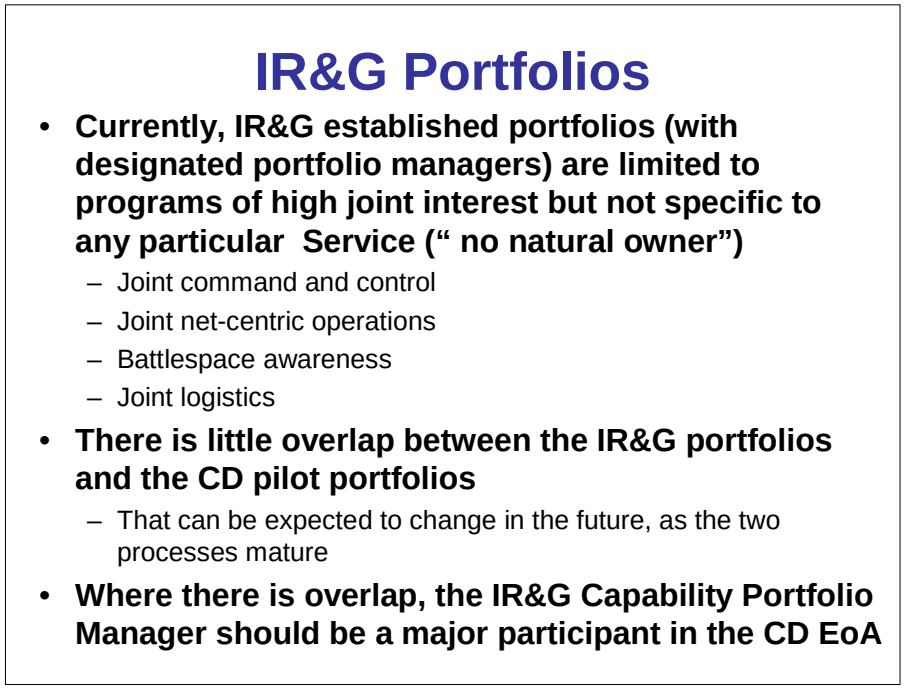

Figure 15. Relationship between IR&G and CD Portfolio Analysis

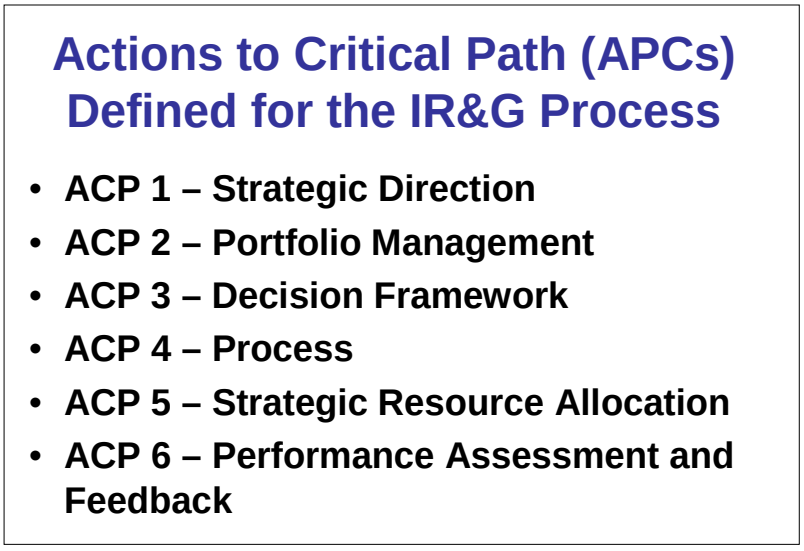

Figure 16. The IR&G Actions to Critical Paths

In addition, the initiative establishes four test “Capability Portfolio Managers (CPMs)” in areas “with high joint value, but with no natural owner,” as seen in Figure 15. One of the roles of the CPM is to interact with the CD process for programs falling within the assigned portfolio. The memo states that the CPM should “provide

independent input to the CD decision-making body on capability issues as necessary." No mention is made of the CPM's role in the EoA process; however, as "advocates" of their portfolios, it should be expected that the CPMs would be strong players in the trade-off/divestiture aspects of the CD EoA. Additionally, the portfolio analysis principles outlined in this paper are as applicable to the IR&G Capabilities Portfolio Managers as they are to the CD EoA Study Directors.

Currently, there appear to be no major overlaps among the four CD pilots and the four test CPMs. However, the number of CPMs will expand in the future,[30] so future overlap problems seem inevitable. Furthermore, ACPs number 3 and 4 suggest the objective of much more far-reaching use of portfolio management within the Department. If that transpires, the impact on the CD process could be much more significant. In fact, the logical result would be that *all* the Department's programs would be managed much as has been defined for the CD process. While that is a worthy goal, there are significant obstacles to evolving in that direction, since it would have a large impact on the resource allocation role of the Military Departments.

ACP 4, entitled "Process," contains the CD process as one of its sub-elements. The major difference with the current CD process is that the IR&G version would insert the Under Secretary of Defense (Comptroller) (USD(C)) as a major player. While not explicitly stated, presumably the USD(C) would join the Tri-Chair (thus making it a "Quad-Chair"). Although that idea has clear advantages, the USD(C) may not want to play a strong role in most cases because of the long-range nature of the typical CD outcome.

Recent developments (see footnotes 29 and 30) indicate that Capability Portfolio Management is being considered for insertion into the heart of the DoD Planning, Programming, Budgeting and Execution System. Since both the IR&G and the CD processes are continuing to evolve, it is not possible to assess the full interactions between the two processes at this time. All that can be stated is that there *will* be substantial interactions which need to be carefully managed in the way ahead.

B. JOINT CAPABILITY AREAS AND THE FYDP-JCA MAPPING

Development of the Joint Capability Areas (JCAs) is being led by Joint Staff (J-7), based on direction from the Deputy Secretary of Defense. The first such effort, which

[30] In a December 18th meeting, the DAWG tentatively approved establishment of four additional CPMs--"force support," "force protection," "corporate management and support" and "global security engagement."

began several years ago, resulted in a set of 22 Tier 1 JCAs and 240 Tier 2 JCAs. These were widely promulgated in the Department, and found some use, particularly by the Combatant Commands. There were criticisms, however, that the framework was too complex, had the potential for growth without any natural limits, focused more on inputs than outputs, and was neither mutually exclusive nor exhaustive (in the sense that every Departmental activity could be "binned" into one or more JCA). As a result, in a March 2007 memorandum, the Deputy Secretary directed the Joint Staff to lead an effort to redefine the JCAs. Figure 17 is a very brief overview of the current revised version, which was approved by the DAWG on January 15, 2008. The question we address here is what utility the JCAs will have in portfolio analysis in the CD process.

As seen in the figure, the approved construct is for nine "Tier 1" capabilities that are functionally oriented. The DAWG also approved 35 Tier 2 capabilities, also functionally oriented. CD portfolios, on the other hand, are in most cases going to be mission-oriented, because they will be addressing future capability gaps in the ability of DoD forces to execute required missions. The mission-oriented capabilities are explicitly represented in the Tier 3 and below JCAs. Further decomposition is in progress.

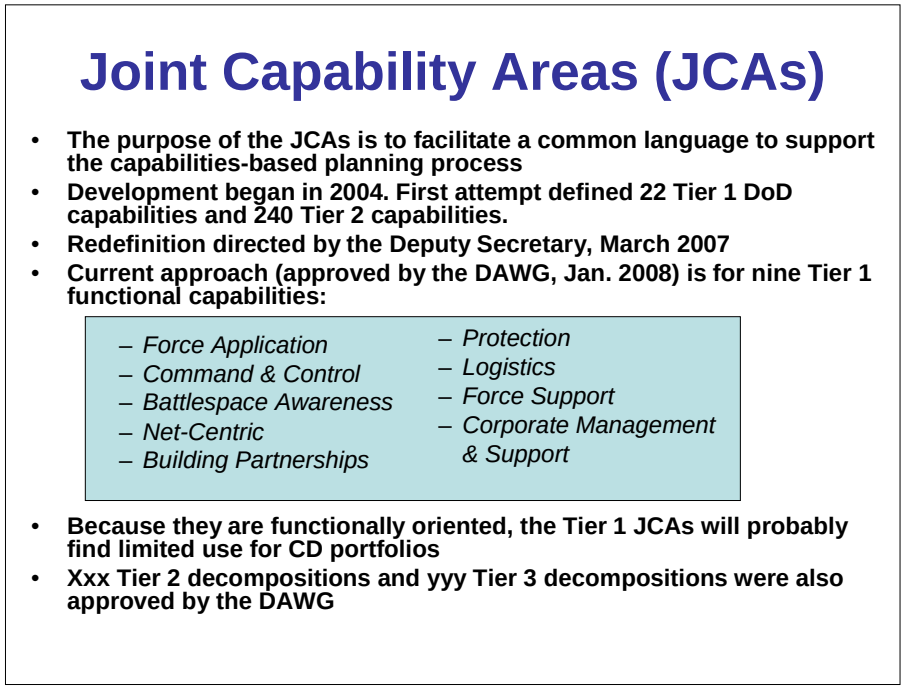

Figure 17. Joint Capability Areas and Their Relationship with CD

As part of the QDR-recommended shift in the Department to capability based planning, in May 2005 the Deputy Secretary asked the Director, Office of Program

Analysis & Evaluation (PA&E) to apply the JCAs "to the program and budget data bases as appropriate prior to the FY08-18 POM cycle," to provide a uniform process to relate JCAs to resources. This was accomplished by establishing a mapping between the program elements (PEs) of the FYDP and the then existing 22 Tier 1 JCAs (see Figure 18 and Appendix D). This, by necessity, is a "many-to-many" mapping, since a particular PE frequently will relate to more than one JCA, and conversely a particular JCA will have many PEs applicable to it. While that characteristic significantly reduces the utility of such a mapping for resource allocation purposes, it, nonetheless, can still provide valuable insights into how the Department plans to allocate its resources vis-à-vis the capabilities that will be produced by that allocation. The ultimate goal is an accurate depiction of the relationships between resources and defense strategy, and to shed light on the age-old question of whether the Department is spending its money consistent with its stated strategic objectives.

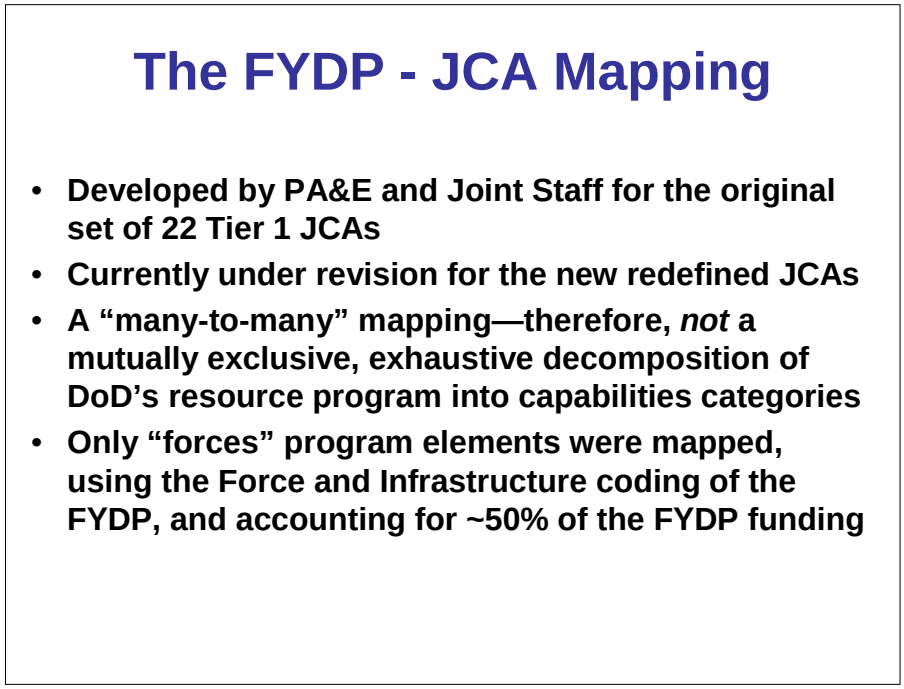

Figure 18. The FYDP—JCA Mapping

Appendix D describes the mapping at a summary level. This study reviewed the results of the mapping in the PA&E data warehouse to get some idea of its utility for defining CD portfolios.[31] The conclusion reached was that the mapping developed for the original JCAs would have some utility in defining CD portfolios and determining the

[31] Access to FDYP data is tightly controlled, so we are unable to provide much quantitative detail of the results in this paper.

resources currently programmed for the elements of the portfolio. That conclusion will likely hold when the new structure is completed and mapped; however, the utility will be largely at the Tier 3 and below level.

C. RELATIONSHIP WITH THE DOD PROGRAM PLANNING PROCESSES AND THE ANALYTIC AGENDA

Figure 19 summarizes the relationship between the CD process and the DoD planning process. The Defense Planning Scenarios comprise a rich set of future conflict situations in which it is plausible that the U.S. would have a vital interest leading to involvement by U.S. forces. These scenarios range from major contingencies (large-scale conflicts with major powers), to insurgencies, peace-keeping, and humanitarian assistance and disaster relief. Each scenario contains options for increasing or decreasing the level of difficulty driven by assumptions. These scenarios are approved at the secretarial level for use in DoD planning and programming. They should thus form the starting point for choosing scenarios for consideration in a CD EoA analysis. They can be enriched as necessary to provide any additional details that may be required for evaluating alternative capabilities.

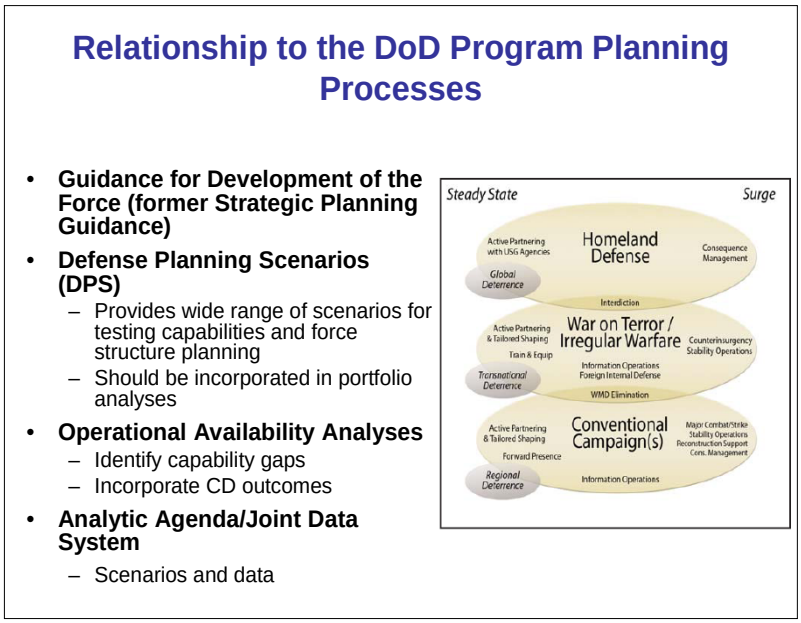

Figure 19. Relationship between CD and the DoD Program Planning Processes

Operational Availability (OA) studies, which address the adequacy of currently planned force capabilities in many of the DPSs, also will in many cases have a strong

relationship with CD EoA analyses, since one of the objectives of the OA studies is to identify gaps in future DoD capabilities.

The Analytic Agenda is an initiative to improve the contributions of analysis to the DoD planning and resource allocation processes. Figure 20 outlines the relationship between the analytic agenda and portfolio analysis in the CD process. The common ground for these two processes is that both concern assessing the future military capabilities of the Department vis-à-vis the future challenges faced and the resources projected to be available. The Analytic Agenda, however, takes a broader perspective than CD portfolio analysis. Nonetheless, since a key goal of the Analytic Agenda is to maintain a "warm base" for modeling and simulation of future conflicts (scenarios, concepts of operation, data, models), it is a highly likely that Analytic Agenda products will provide a valuable starting point for the analyses needed in EoAs.

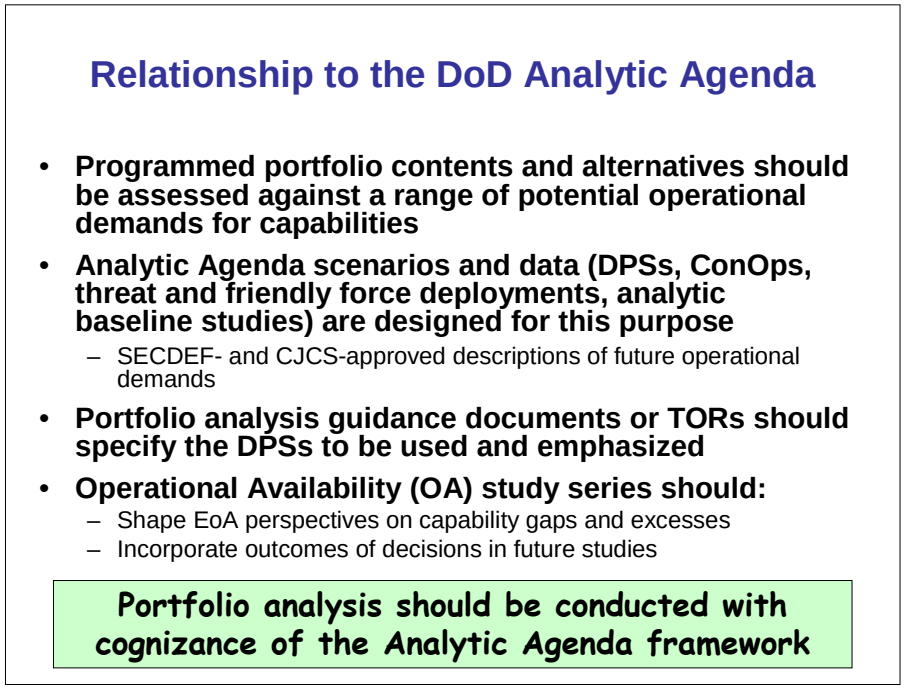

Figure 20. Relationship between CD and the DoD Analytic Agenda

VII. CONCLUDING REMARKS, FINDINGS AND RECOMMENDATIONS

This paper has explored a number of important considerations in conducting Concept Decision Evaluation of Alternatives, particularly with regard to the key process of defining and analyzing the capability portfolio relevant to the mission area. The *raison d'être* of a CD review is to address a critical capability gap that has emerged through other processes– and to do so early enough so that the resulting decision can be integrated into the Department's long range budget plans without undue disruption. The normal expectation is that currently unplanned resources will be required to provide capabilities to close the gap.[32] Future resources are almost always in tight supply. Thus, in the absence of increased total funding for DoD, there is a compelling need to identify, as a source of funds, things that are currently funded but that are assessed to be less critical in the future than capabilities needed to close or reduce the gap. That task ranks, along with the sound construction and analysis of gap-filling capability alternatives, among the key tasks the EoA study team must address.

This paper suggests a theoretical framework for portfolio analysis in the CD context. That approach must be tempered when it encounters the real world. The need for EoA study teams, some of them cross-service in composition, to identify through analysis a suitable source of funding from within portfolio-related programs is a difficult challenge. But unless the discipline needed to do so is exercised, the primary benefit of "portfolio management" will be lost, and the decision-making process will revert to the historical practice in which the requirements community, aided and abetted by the acquisition community, identified effective ways to reduce risk by spending more money than currently planned, thus leaving to the program/budget community the task of finding funding sources for those initiatives. The result would be a less coherent overall defense program than would be the case if each set of mission area experts maximized their own capabilities within currently planned spending. After accomplishing optimization within portfolios, a higher-level risk assessment and reallocation decision forum—such as the

[32] It is conceivable of course that the gap problem can be solved by reconfiguration of existing capabilities or other measures not requiring reallocation of resources. Such "trivial solutions,' however, will probably have been found before the need for a CD is determined.

current DAWG process—could conduct the essential cross-mission risk assessments and reallocations prior to finalizing the next FYDP.

Not only can the approach described in this paper benefit the ongoing four CD pilot EoAs, it also has direct applicability to the Department's larger portfolio management initiatives being pursued under the QDR-directed IR&G process. The portfolio analyses being conducted in both the CD and IR&G pilots should be examined for lessons applicable to creating a more complete and accurate "baseline" procedure to be used even more broadly throughout the Department as the portfolio management concept continues to expand.

Ultimately the success of the CD initiative will be determined by the prevalence of "capability" acquisition programs that provide timely response to the needs of the future U.S. combat forces. That success depends in turn on sound, timely analytical support to the responsible DoD decision-making body. The principles articulated in the paper are intended to further that end.

Although it was not a primary purpose of this paper to develop findings and recommendations, four recommendations have emerged from the effort:

- The two ongoing DoD portfolio management experiments, i.e. within the CD and the IR&G processes, should be harmonized. "Lessons learned" from those experiments should be assessed, documented, and shared between the two communities.
- The need for better analytical tools applicable to DoD portfolio management is evident. Starting from the "lessons learned" analysis recommended above, gaps in current analytical methodologies, tools and data should be documented and approaches to mitigating those gaps identified. Once that is accomplished, an effort to develop improved methodologies should be undertaken.
- The systems engineering process should be applied early in systems acquisition to evaluate technical and engineering risk. To avoid initiating programs prematurely, such an evaluation should become part of the basis for a decision on the next stage of development.
- The current uncertainty needs to be resolved concerning the extent to which the CD process will continue to be used:
    - Primarily for reaching decisions strictly on materiel solutions, ***or***
    - As a broader forum wherein materiel and non-materiel solutions are considered along with tradeoffs on equipment quantities and associated force structure.

Appendix A
FORMAL MODEL OF PORTFOLIO ANALYSIS

The charts below present a formal mathematical model corresponding to the descriptive model presented in Section IV of the main paper.

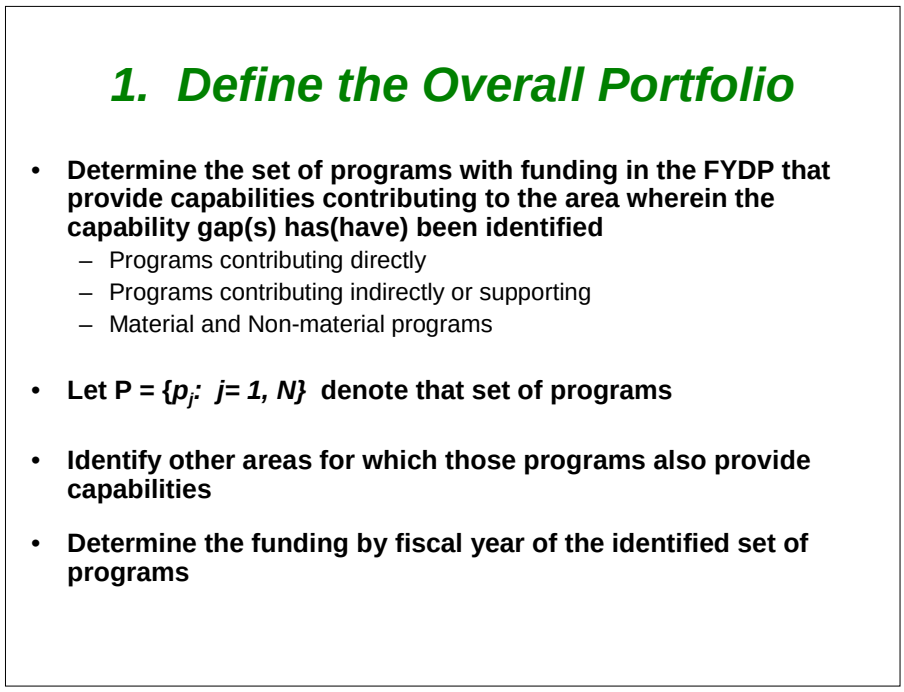

Figure A-1. Defining the Overall Portfolio

2. Define the Solution Sets

- **Define a set of alternatives that may be capable of filling the identified gap**
  - Mods to existing weapon systems
  - New acquisition system starts
  - DOT_LPF changes
- **Alternatives will typically be constructed as combinations of the above:**

$A_i = \{x_{ik}, k = 1,\ldots N_i\}$, each x_{ik} is a program or initiative providing or supporting a capability contributing to closing the gap

Figure A-2. Defining the Solution Sets

3. Trade-Off analysis

Let $C(A_i)$ be the cost of alternative A_i

Let $C(p_j)$ be the cost of existing program p_j

Let **$\{p_j: j \in R\}$ be a subset of P consisting of the programs to be retained (*R* is an index set for the programs retained)**

Thus, $\{p_j : j \notin R\}$ is the set of programs to be divested

Let $E(S)$ be the effectiveness of a set *S* of programs (a member of *S* is either an A_i or a p_j)

Analytical objective:

Solve for A_i and R such that

$E(A_i \cup \{p_j: j \in R\})$ closes the capability gap,

and the set of programs $\{p_j : j \notin R\}$ can be divested with (collective) acceptable risks, while minimizing:

$C(A_i) - \sum C(p_j : j \notin R)$

Figure A-3. Making the Trade-off Analysis

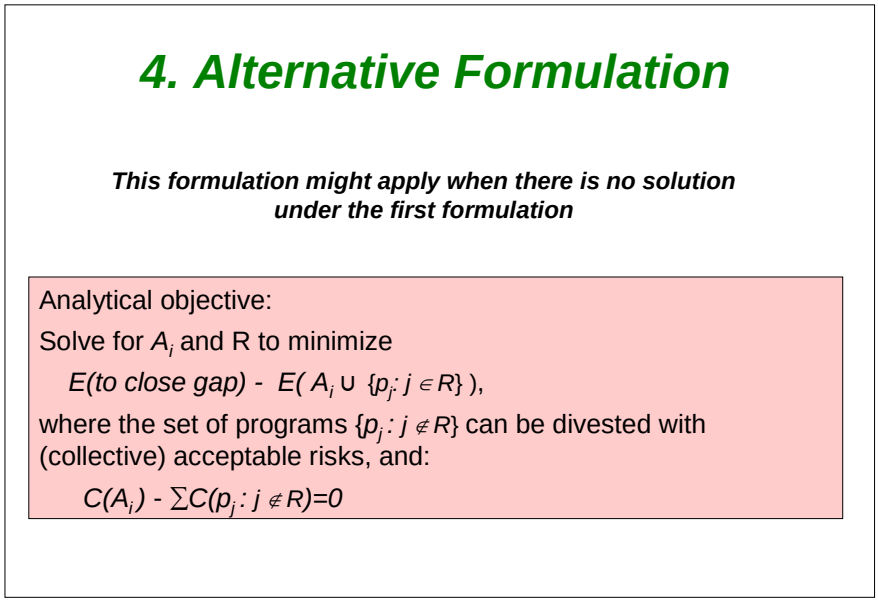

Figure A-4. An Alternative Formulation of the Optimization Process

Appendix B
ASSESSING TECHNICAL AND ENGINEERING RISKS IN THE CONCEPT DECISION PROCESS

1. Introduction

This appendix is organized as follows:

- Section 2 describes how the new Concept Decision (CD) process will interact with acquisition management;
- Section 3 summarizes policy on technical and engineering risk;
- Section 4 provides data to support the importance of the technology maturity component of technical risk to acquisition;
- Section 5 identifies some best practices for risk assessment in the Evaluation of Alternatives—the analytical basis for the CD;
- Section 6 is a summary.

2. The Concept Decision Process and Acquisition Management

The Concept Decision that follows an Evaluations of Alternatives (EoA) may initiate one or more materiel investments essential to a particular materiel alternative, or to different competing materiel solutions. After the CD review, there are three possible entry points into the acquisition management framework, based largely on the technical and engineering risk:

- **Milestone A.** When the prospects for risk reduction in a short period of time appear promising, entry into the Technology Development phase of the acquisition process may be approved to provide the time and resources to reduce risk sufficiently for system development.[1]
- **Milestone B.** When all of the critical technologies have been demonstrated in a relevant environment and other technical risks for system integration appear manageable, entry into the System Development and Demonstration phase may be planned, contingent upon completion of the remainder of the statutory and regulatory requirements for Milestone B. Approval of Milestone B constitutes the formal start of all DoD acquisition programs (except for naval ships) for Congressional reporting purposes and requires that the next Future

[1] Such approval usually encompasses funding just the effort needed to achieve the Milestone B criteria.

Years Defense Program (FYDP) reflect the future years funding that had been approved by the Defense Acquisition Executive.

- **Milestone C.** If the design is complete and production risks appear low, then Low Rate Initial Production may be planned contingent upon completion of the remainder of the statutory and regulatory requirements for Milestone C.

This appendix focuses on the evaluation of technical risk in the materiel solution space. For potential new materiel solutions, an important underlying principle of the CD process is to invest sufficiently in early risk reduction efforts to meet the formal criteria for acquisition program initiation and in doing so limit the risk of subsequent expensive delays and cost growth. That principle implies that the analysis performed during the EoA should assess technical and engineering risks in the alternatives under consideration and then determine, based on that assessment, the extent to which:

- Additional investments should be made in the alternative at this time because of the extent of the cost and/or risks, or the availability of other alternatives, or the acceptability of the "status quo;"
- Specific S&T investments should occur before a decision can be responsibly made on whether the alternative should enter the acquisition management process; or
- An alternative is mature enough to support entry into the formal acquisition management process. This includes technical maturity, as well as readiness within the broader infrastructure to support design, test and evaluation, producibility, and to make informed judgments about supportability. These features are discussed in more detail in Section 4.

The Concept Decision that follows an EoA may lead to an Acquisition Decision Memorandum that initiates one or more materiel investments essential to a particular materiel alternative, or to different competing materiel solutions. When the risks are too high to enter the formal acquisition management process as outlined in Section 2, materiel investment may be strictly in Science and Technology (S&T).

- **S&T only.** If the alternative holds a great deal of promise for closing a capability gap, but the risk of maturing its enabling technologies in a short period of time is high, then an additional S&T investment outside of the formal acquisition management process may be a selected course of action.

3. Technical and Engineering Risk Policy

Several paragraphs in DoDI 5000.2 provide policy on assessing technical risk: "The management and mitigation of technology risk, which allows less costly and less

time-consuming systems development, is a crucial part of overall program management and is especially relevant to meeting cost and schedule goals."[2]

- As part of the requirements generation process, it states: "The capability needs and acquisition management systems shall use Joint Concepts, integrated architectures, and an analysis of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) in an integrated, collaborative process to define desired capabilities to guide the development of affordable systems. … Representatives from multiple DoD communities shall assist in formulating broad, time-phased, operational goals, and describing requisite capabilities in the Initial Capabilities Document (ICD). They shall examine multiple concepts and materiel approaches to optimize the way the Department of Defense provides these capabilities. The examination shall include robust analyses that consider affordability, technology maturity, and responsiveness."[3]
- As part of Concept Refinement, it states: "The ICD and the AoA plan shall guide Concept Refinement. The focus of the AoA is to refine the selected concept documented in the approved ICD. The AoA shall assess the critical technologies associated with these concepts, including technology maturity, technical risk, and, if necessary, technology maturation and demonstration needs."[4]

This policy will remain applicable to the EoA in the CD process when the broader Joint Capabilities Document (JCD) precedes narrower ICDs and the Analysis of Alternatives (AoA) replaces the EoA. The need for *robust analyses … of technology maturity* in the requirements generation process applies to the Functional Solutions Analysis (FSA)-like part of the EoA. The *assessing of… technical risk …* as part of the Concept Refinement Phase applies to the AoA-like elements of the EoA.

4. Relationship Between Immature Technologies and Cost/Schedule Growth

Formally initiating acquisition programs by contracting for System Development and Demonstration that relies (improperly) on immature technologies frequently leads to cost growth and schedule slippage.

Technology maturity is usually measured by technology readiness levels (TRLs) for a Technology Readiness Assessment (TRA) conducted at a Milestone decision.[5]

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2 DoDI 5000.2, paragraph 3.7.2.2.
3 DoDI 5000.2, paragraph 3.4.1.
4 DoDI 5000.2, paragraph 3.5.3.
5 The use of TRLs originated with the National Aeronautics and Space Administration (NASA) in the 1980s.

TRLs indicate what has been accomplished in the development of a technology across various levels of utility to the user—ranging from theory, to laboratory demonstration, to prototype demonstration, to proof in the field. TRLs do not measure whether the technology or the design is right for the job, the difficulty of system integration, or how easy it will be to reach the next level. TRL 6, which determines that a system/subsystem model or prototype has been demonstrated in a relevant environment, is the DoD-established minimum maturity criterion for formal program initiation and entry into full System Development and Demonstration. See Figure B-1 for hardware and software TRL definitions.

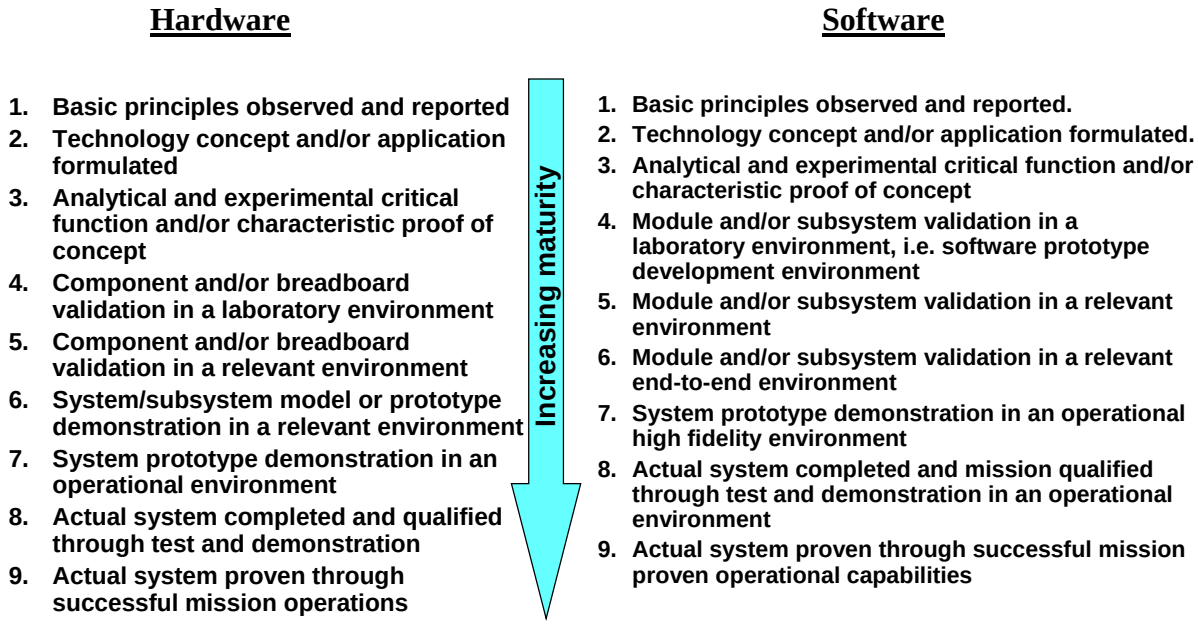

Figure B-1. Definition of Technology Readiness Levels

The Government Accountability Office (GAO) has attempted to quantify the effects of immature technologies on acquisition programs.[6] According to a 2005 GAO review of 54 DoD programs:[7]

- Programs that started with the preferred level of technology maturity (TRL 7) averaged 9% development cost growth, a 7 month schedule delay, and a 1% acquisition unit cost growth; and

[6] DoD did not make any general comments on these GAO reports; only technical comments were provided. We are not aware of any recent systematic DoD efforts to develop similar quantitative estimates of the impact of technology immaturity.

[7] Defense Acquisitions: Assessments of Selected Major Weapon Programs, GAO-05-301, March 2005.

- Programs whose technologies did not meet that criterion averaged 41% development cost growth, a 13 month schedule delay, and a 21% acquisition unit cost growth.

The 2006 version of the same report had analogous findings based on 52 programs:[8]

- Programs that started with technologies at the TRL 7 level averaged 4.8% development cost growth and a 1% acquisition unit cost growth
- Programs that used less mature technologies averaged 34.9% development cost growth and a 27% acquisition unit cost growth

The 2006 report also provided some results based on a TRL 6 minimum criterion for mature technology. While the differences are not as dramatic, the effect is similar.

- Programs that started with such technology maturity averaged 18.8% development cost growth; and
- Programs that started with less mature technologies averaged 34.6% development cost growth.

The GAO analyses did not examine the extent to which factors other than technology immaturity, such as inaccurate cost estimation or requirements creep, led to the observed cost and schedule growth. Consequently, causality cannot be rigorously proven. However, the linkage between technology immaturity and these other factors is so strong, it is reasonable to conclude that technology maturity contributes in a major way to program stability and predictable outcomes.

5. Best Practices for Considering Technical and Engineering Risk in an EoA

We have seen strong evidence that technical risk contributes to program instability. However, only knowing about the technical risk is not a sufficient basis for making a materiel investment decision. Further analysis of this risk should be conducted to support an assessment of the degree of difficulty of advancement[9] of the alternative along with the technical suitability for the application. This is the information most useful to decision makers in deciding whether to invest, and if so, the nature of the investment.

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[8] Defense Acquisitions: Assessments of Selected Major Weapon Programs, GAO-06-391, March 2006.

[9] Ideas presented in this section are adapted from Systematic Assessment of the Program/Project Impacts of Technological Advancement and Insertion; James W. Bilbro; George C. Marshall Space Flight Center; December, 2006.

Conceptually, there is a third factor that may be considered in such an assessment—the overall maturity of the technical solution. Three broad classification levels may be used:

- It does not exist (only a paper concept).
- It has been demonstrated in a laboratory.
- It is commonly available.

Several complicating factors may decrease the utility of this assessment factor. For example, a software algorithm may not exist but may be demonstrated very quickly. On the other hand, in the hardware world a major scientific breakthrough may be needed to demonstrate something in a laboratory environment. Therefore, to simplify the assessment process, it should be sufficient to focus on the advancement degree of difficulty in the context of the acquisition management framework. Advancement degree of difficulty should be assessed on the basis of the difficulty in achieving the next acquisition milestone given the anticipated entry point in the process.

Both the degree of difficulty of advancement along with the technical suitability for the application should be assessed on the basis of the status of the alternative in five areas of technical risk:

- Technology maturity [note that examination of technology maturity during an EOA is **not** a formal Technology Readiness Assessment],[10]
- Test and evaluation readiness,
- Design and integration readiness,
- Manufacturing readiness, and
- Supportability readiness.

To make such an assessment, certain information must be determined using a systems engineering process where requirements analysis, functional analysis, and conceptual design take place iteratively and recursively. To complete this analytical systems engineering process, it will be incumbent on the EoA study team to make (and

[10] TRAs are required at Milestone B and C and at program initiation, typically Milestone A, only for ships. A TRA is a systematic, metrics-based process and accompanying report that assesses the maturity of certain technologies [called Critical Technology Elements (CTEs)] used in new acquisition programs. Technology Readiness Levels (TRLs) are used to describe the maturity of CTEs. The use of TRLs is also **not** appropriate for the assessment of technology maturity during an EoA. During an EoA associated with an early milestone there is no program of record. So, for example, it is not possible to demonstrate a component or sub-system in a relevant environment because (1) the system has not been fully defined; (2) the relevant environment may not have been completely defined; and (3) there is no draft Capability Development Document on which to base technical performance goals.

document) assumptions about the unknowns based on the Functional Needs Analysis (FNA), the JCD, and the scenarios being used to evaluate alternatives. This sets the conditions for the CD by defining what is needed. It does not specify how things should be done. Elements include:

- Determining the capabilities to be provided on the basis of the FNA.
- Postulating the nature of the materiel solution (the type of system it will be and how it will be used to accomplish its mission) under consideration to close the capability gap.
- Making an initial determination of the functions necessary to meet the required performance characteristics to provide the desired capability on the basis of measures of effectiveness articulated in the JCD.
- Estimating plausible system operational requirements, operational effectiveness/utility, and cost based on assumptions about a system concept and key characteristics.

These assumptions should not be made by the technical community in a vacuum. There must be strong communication with the user community. In that way, the functional analysis ultimately forms a bridge between *requirements* and *system design or systems architecture*, by considering alternative means of performing the functions and by trading among scarce resource parameters (such as cost, weight, power, and space). Each element influences and is influenced by the others as tradeoffs are made to discover the best solution on an iterative basis.

The information generated by the systems engineering process can be used to make a preliminary determination of enabling technologies for the alternative under consideration by systematically considering all elements of the work breakdown structure or systems architecture. It is not necessary to evaluate risks associated with all technologies. The assessments should be applicable only to those technologies that pose the greatest risk to the success of a potential materiel solution. Therefore technologies that affect cost in a significant way should be considered as well as those technologies essential for mission performance. If the technology has been used before in a similar environment, risks are likely to be much better understood. Therefore whether a technology is “new or novel” is another important criterion.

Critical enabling technologies are those that have the highest risk associated with them. Such risk is determined by two criteria.[11] The first criterion is criticality to closing the capability gap. At least one of the following questions must be answered "yes."

- Does the technology enable an improvement over current performance levels necessary to achieve a predicted reduction to the capability gap?
- Does the technology have a significant impact on when the capability gap will be reduced?
- Does the technology have a significant impact on the extent of the offsets used to resource the life cycle costs of the materiel solution?

The second criterion is "new or novel." At least one of the following questions must be answered "yes."

- Is the technology new or novel?
- Is the technology modified?
- Has the technology been repackaged such that a new relevant environment is realized?
- Is the technology expected to operate in an environment and/or achieve a performance beyond its original design intention or demonstrated capability?

In general, greater knowledge implies lower risk. Knowledge about the technical solution along with the performance needs that the solution should support enable a better understanding of the work effort required to achieve the next acquisition milestone. *The CD decision-making body must be given an understanding of this work effort, the technical risk, the cost, and the performance results to make a decision on a materiel investment.*

Assessing the advancement degree of difficulty implicitly requires the use of a scenario to make sound decisions about the future. Peter Schwartz[12] suggests an approach to scenario building. An important first step is tailoring the scenario to facilitate the decision to be made. The next step is to determine the controllable and uncontrollable elements of the relevant environments. The elements should be ranked based on their importance and their certainty in order to flesh out the scenario and to assess their implications on the scenario. Finally, key indicators of either the potential success or failure of the technical approach should be identified.

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[11] Adapted from the process used to determine critical technology elements for a TRA.

[12] Peter Schwartz, *The Art of the Long View*, Currency Doubleday, 1991.

The following four bullets summarize degree of difficulty of advancement and technical suitability considerations in the five areas of technical risk as a function of materiel investment decisions (as introduced in section 2).

- **S&T only**

  The implication of an S&T only investment is that the advancement degree of difficulty is too high to enter the formal acquisition management process because the technology is too immature. This is the case if the approach for continued development is similar to existing experience in, at most, a small subset of the critical areas. In other words, there are so many more unknowns than knowns, even the approach is nebulous. As far as suitability is concerned, it is unlikely that any determination can be made.

  It would be unusual for potential solutions that are very immature technically to be offered as an alternative in the CD process. Such alternatives would normally be eliminated during the EoA screening process prior to the AoA-like analysis. A particular technology may, however, offer an especially high potential for closing a capability gap. In such a case, even though there is no clear path for maturing the technology, the EoA may highlight that technology for investment, regardless of any existing S&T projects in the area. Such an investment should provide resources to advance and characterize performance in some environment within a specified time frame. The technology could be reconsidered for inclusion in a materiel solution at a later date if the effort were successful.

  No formal acquisition management requirements must be fulfilled after the CD since these activities are outside of the acquisition management process.

- **Milestone A**

  Feasibility to enter the acquisition management process at Milestone A implies that both the advancement degree of difficulty and the technical suitability are moderate. This is the case when (1) it is reasonable to believe that the technical solution is "right for the job" and (2) the approach for continued development ranges *from* well within experience levels (a single development approach is adequate) *to* sufficiently similar to existing experience to warrant comparison in most critical areas (dual development approaches should be pursued). Key elements of the development approach vary as a function of the technical risk areas as follows:

  - For technology maturity, the development approach applies to a technology maturity plan leading to critical technologies being demonstrated in a relevant environment as required before a subsequent Milestone B

- For test and evaluation readiness, the development approach applies to test equipment, test tooling, test measurement systems, software
- For design and integration readiness, the development approach applies to functional requirements, interfaces, constraints
- For manufacturing readiness, the development approach applies to materials, machines, tooling, metrology, software
- For supportability readiness, the development approach applies to maintainability, reliability, support equipment, logistics footprint

While a Milestone A approval does not guarantee program initiation at a later time, it does imply such potential. Therefore ,the Concept Decision should also establish requirements in the form of criteria to be met and information to be determined, in order to warrant consideration for a Milestone B. Such criteria and information should include the funding, the schedule, and the performance characteristics necessary in all technical and engineering risk areas. Decision makers should also consider these requirements when assessing whether the technical and engineering risk is sufficiently low, despite the fact that there are uncertainties concerning how development will be accomplished.

The Department's typical approach to "risk" applies to well-defined quantifiable activities. This approach does not capture much of the "technical risk" at a Concept Decision review for alternatives going to Milestone A, because that risk stems more from missing information (unknown unknowns), than from uncertainty about the outcome of forecast events. In addition, there is no formal process for dealing with this type of technical risk. Despite the lack of a formal process, identification and mitigation of this "ignorance driven" technical risk should be aggressively pursued and well funded because the cost of post-Milestone B problems dwarfs the resources necessary to assure a successful outcome from this S&T phase. The exit criteria established at such early CDs for subsequent Milestone B consideration should take this into account.

Three to four months after a Concept Decision to proceed, an early TRA should be completed. One important outcome of the early TRA is a Technology Maturation Plan[13] that should be integrated into the Technology Development Strategy and should be consistent with the Test and Evaluation Strategy and the Systems Engineering Plan (SEP) that will be needed for Milestone B. These documents should refine the preliminary plans formulated during the EoA for achieving the technical risk reduction necessary for Milestone B approval. If the results of these efforts do not validate the assumptions underlying the CD, then the decision-making body should be reengaged to determine an alternate course of action.

[13] The Plan may be updated during Technology Development as long as all changes are coordinated with the Component S&T Executive and the DUSD(S&T).

- **Milestone B**

Feasibility to enter the acquisition management process at Milestone B implies that the advancement degree of difficulty is low and the technical suitability is high. This is the case when (1) it is clear that the technical solution will satisfy all constraints and (2) the approach for continued development should be based on having a demonstrated prototype in all areas, but some applications may require modification of that prototype for the situation at hand. Key elements of the development approach vary as a function of the technical risk areas as follows:

- For technology maturity, the development approach applies to all critical technologies being demonstrated in a relevant environment.
- For test and evaluation readiness, the development approach applies to test equipment, test tooling, test measurement systems, software, …
- For design and integration readiness, the development approach applies to functional requirements, interfaces, constraints, …
- For manufacturing readiness, the development approach applies to materials, machines, tooling, metrology, software, …
- For supportability readiness, the development approach applies to maintainability, reliability, support equipment, logistics footprint, …

Entry into the acquisition management process at Milestone B is contingent on completing the statutory and regulatory requirements that demonstrate the technical readiness to proceed. This includes the TRA, the Test and Evaluation Master Plan (TEMP), perhaps an updated AoA, and the SEP. The analysis behind and the preparation of these documents must validate the conclusions reached during the EoA concerning technical risk. If that is not the case, and the technical risk for entry into Milestone B is too high, then the request for Milestone B approval should be deferred and the decision-making body should be reengaged to determine an alternate course of action.[14]

- **Milestone C**

Feasibility to enter production at Milestone C implies that the advancement degree of difficulty is extremely low and technical suitability is proven. This is the case when the technical suitability and the approach for continued development are based on having a demonstrated production system in all areas.

[14] With regard to technology maturity, to better enforce compliance with DoDI 5000.2, Congress created Section 2366a of title 10, United States Code, as enacted by Section 801 of the National Defense Authorization Act for Fiscal Year 2006 (Public Law 109-163) and as amended by Section 805 of the National Defense Authorization Act for Fiscal Year 2007 (Public Law 109-365). This legislation requires the Milestone Decision Authority (MDA) for a Major Defense Acquisition Program to make certain certifications concerning adherence to DoD's acquisition policy prior to Milestone B or Key Decision Point B approval of program entry into System Development and Demonstration. One such certification is that "the technology in the program has been demonstrated in a relevant environment." Another is that "appropriate market research has been conducted prior to technology development to reduce duplication of existing technology and products." If either condition is waived, the MDA must provide the rationale to Congress based on National Security concerns.

Key elements of the development approach vary as a function of the technical risk areas as follows:

- For test and evaluation readiness, the development approach applies to design for testability.
- For design and integration readiness, the development approach applies design for producibility.
- For manufacturing readiness, the development approach applies to manufacturing process flow, manufacturing process variability, yield
- For supportability readiness, the development approach applies to design for availability, life cycle cost

As was the case for Milestone B, all statutory and regulatory requirements must be fulfilled. These include a TRA, a TEMP, and a SEP. The analysis behind and the preparation of these documents must validate the conclusions reached during the EoA concerning technical risk. If that is not the case, and the technical risk too high to enter Low Rate Initial Production, then the request for Milestone C approval should be deferred and the decision-making body should be reengaged to determine an alternate course of action.

6. Summary

The CD process is designed to accelerate the delivery of joint warfighting capabilities, address resource/funding constraints early, and tailor analysis to support the decision at hand. To accomplish this, technical risk must be adequately addressed to achieve program stability and predictable outcomes. Technical risk policy is written for the current acquisition management process and must be adapted to the new CD process. The best practices for doing this are a function of the type of materiel investment decision being considered for a Concept Decision.

The EoA should assess the advancement degree of difficulty and the technical suitability for the application for every area of technical risk. The results should be used to eliminate alternatives where the technological risk is too high and to determine the appropriate entry point into the acquisition framework for others. While the EoA process itself may be technically sufficient for the alternative to enter the acquisition management framework at Milestone A, greater technical knowledge obtained from a more refined technical analysis is necessary before going further. These analyses should be used to validate the EoA results before seeking a Milestone B or C approval.

Implementing an effective approach for monitoring technology maturity in an EoA will help shift the focus of acquisition management from the System Development and Demonstration Phase to the period of time prior to the formally defined “acquisition

management” phase where broad options are still available and can be aligned for closing capability gaps.

Appendix C
ENABLING STRATEGIC CHOICE THROUGH INSTITUTIONAL REFORM AND GOVERNANCE

QDR Direction for Institutional Reform and Governance

The 2005 Quadrennial Defense Review (QDR) provided the following direction with respect to Institutional Reform and Governance (IR&G): (1) Create or invigorate empowered horizontal organizations to integrate priority areas; (2) Improve Department effectiveness and efficiency to include exploring a portfolio based approach (emphasis added) to defense planning, programming and budgeting; (3) Move toward common data structures/approaches at the enterprise level; and (4) Implement new acquisition policies, procedures and processes for dramatic improvements by all measures. The Concept Decision (CD) process is included under item (4).

A March 15, 2007, memorandum (subject: Institutional Reform and Governance Actions to Critical Paths (ACP)) by the Deputy Secretary of Defense initiates implementation of the IR&G approach. This appendix summarizes the Deputy Secretary's memo and its attachments.

Summary of the Deputy Secretary's Memorandum dated March 17, 2007

The memo states a need to "move toward a general management framework that provides clear and executable strategic direction for the current, mid and far term." The initiative is divided into six ACPs:

- ACP 1 – Strategic Direction
- ACP 2 – Portfolio Management
- ACP 3 – Decision Framework
- ACP 4 – Process
- ACP 5 – Strategic Resource Allocation
- ACP 6 – Performance Assessment and Feedback

The IR&G initiative appears to be quite far-reaching in its overall goal of reforming strategic and fiscal management of DoD. Related activities are as follows: (1) Capability Portfolio Management Test Cases, (2) Concept Decision/Time Defined Acquisition, (3) Evaluation of Alternatives (EoA), (4) Capital Accounts, (5) "Little A" Acquisition Reform Initiatives, (6) Data Transparency Initiatives (numerous) and (7) Joint Task Assignment Process.

Institutional Reform and Governance Framework

At the highest level IR&G views the following "Corporate decision lanes" (also referred to as "general management decision lanes" in the attachment to the Deputy Secretary's memo) as a way to break down departmental activities into more manageable components:

- Employ the force (Timeframe: now)
  Operates with what we have available and provides performance feedback to inform future decision making
- Manage the force (Timeframe: 1-3 years)
  Prepares, supports, sustains, and aligns what we have to what we need
- Develop the force (Timeframe, > 3years)
  Builds capability and capacity (DOTMLPF) to fulfill future joint customer needs (fits supply to demand)
- Corporate support: Administration and support activities

The following paragraphs summarize the attachment to the DepSecDef memo (which describes the ACPs in detail), highlighting in particular those sections that have an impact either directly or indirectly on the CD process.

ACP 1 – Strategic Direction. This ACP stresses the need to identify capability gaps for near, mid and far term. Under the heading "Prioritize Capability Gaps for FY 2010," "Action lead" is assigned to the JROC with a requirement to "report process" to the DAWG in May 2007. In addition, under the heading "Build a Better Planning Guidance Methodology for FY 2010," it is specified that the "guidance will incorporate capability priorities, gaps, …and define metrics to be used by [the decision lanes] to determine how well we are executing our strategic plan." Action lead is assigned to PDUSD(Policy). Guidance is to be published in November 2007.

ACP 2 – Portfolio Management. This ACP starts as follows:

> Statement of Expectations: There is value added in the ability to view department activity through a capability portfolio lens. In certain capability areas (those with high joint value, but with no natural owner) there is value in establishing and monitoring an enterprise wide capability portfolio proponent.

And continues:

> …the capability portfolio manager (CPM) is responsible for advocating a balanced set of capabilities for a defined capability portfolio within a given resource constraint. CPMs will provide portfolio-specific guidance consistent with the Department's planning guidance to the Services and Defense Agencies. They will also be responsible for assessing the implementation of that guidance and serving as an independent voice in existing decision processes. These portfolio managers are afforded direct access to the [DAWG, JROC, DAB] and other established forums to raise portfolio related issues when necessary.

It is not specified by what process such issues are to be raised. The attachment goes on to cite existing "Portfolio Management Experiments" for Joint Command and Control, Joint Net-Centric Operations, Battlespace Awareness, and Joint Logistics and states that they "shall continue to evolve to fulfill this role." It also states that "The determination to establish other portfolio managers will be made on a case by case basis, once the existing portfolios are operating effectively in this vision." There is no elaboration as to what this actually means or by what process it will occur.

The CPMs will also:

> Develop and present a fiscally informed Capability Portfolio Strategic Plan that derives portfolio strategic objectives from existing strategic guidance, projected capability mix, dependencies with other capability portfolios, performance metrics, and actions – including needed analysis – to meet objectives and mitigate risk. Address how changes to FY 2009 and beyond will be developed and proposed to better align resources to the capability portfolio strategic plan.

The CPMs were directed to present their capability portfolio strategic plans to the DAWG in March 2007. For the FY 2009 Program Review, the CPMs will:

- Have the authority to access and work with components to develop FY 2009 change proposals to ensure alignment to the Department's capability goals as articulated by the capability portfolio plan and submit independent change proposals if there is disagreement with the components.
- Present to the DAWG an independent portfolio assessment of the FY 2009 Program and potential programmatic issues to be addressed in the FY 2010 planning guidance.

For FY 2010, the CPMs will:

> Provide capability planning guidance consistent with the Capability Portfolio Strategic Plan as part of the FY 2010 planning guidance. Propose other potential CPM authorities for the FY 2010 Program Review cycle. Present resource requirements needed to efficetively operate as portfolio managers.
>
> Timeline: CPMs to present draft guidance and other potential authorities to the DAWG in October 2007.

The next section is explicit in reference to the CD process:

> Capability Requirements, Solution Determination, Implementation Monitoring, CPM Performance Assessment, CPMs will:
>
> • Work within the concept decision process and provide independent input to Concept Decision Tri-chair-USD (AT&L), VCJCS, D, PA&E, on capability Issues as necessary.
>
> • Work within the established JCIDS process to include working with Functional Capabilities Boards in fleshing out requirements and provide independent input to the JROC on capability issues as necessary.
>
> • Monitor implementation of existing programs from a system of systems perspective to ensure alignment to cost, schedule, and portfolio strategy and provide an independent voice to the appropriate process owner if performance monitoring indicates a deviation from accepted risk levels.
>
> • Assess their management effectiveness and impact on decision processes against a set of criteria established by the Deputy Secretary on an annual basis and present the results to the DAWG starting in December 2007.
>
> o IR&G will work with CPMs to clearly define the Deputy's performance

So far, only four CPMs have been identified, and there appears to be little overlap with the four CD pilots. So questions as to how these interactions will occur do not require resolution until either a CD is proposed that would fall into the existing four CPM portfolios, or new CPMs are established that encompass an already-defined or to-be-established CD. When either event occurs, the following questions will need to be addressed:

- What does it mean to provide "independent input?"
- How will the CPMs play in the EoA process and particularly the trade-off process? Since the DepSecDef memo says the CPMs are to be "advocates" for their portfolio, they may not be amenable to identifying tradeoffs within their portfolios.
- The fourth bullet in the above extract asked the CPMs to assess their own management effectiveness. By what means?

ACP 3 – Decision Framework. This ACP outlines how a new strategy and resource decision process for the Department might evolve. It starts with the following:

> Statement of Expectation: The Department needs an overarching framework to create a common sense of value; allow strategy to outcomes linkage; and enable integrated management information and transparency across missions, functions, organizations and processes.

The ACP continues with an outline of a portfolio/capability-oriented process to relate "current and future operational goals to capabilities and link them to core

Department management processes…" It calls for the development of "experimental portfolio data displays for the FY 2009 budget cycle to determine full-up implementation requirements approach for FY 2010 cycle" for presentation to the DAWG. Next it addresses the need "to improve data integration, transparency and agility" to support "enterprise decision making and performance assessment" and "metrics [to] measure progress toward [the] effort's strategic objectives." Finally, the ACP says to: "Explore Realigning Department Activity by the General Management Framework" through:

> …an external evaluation of the general management framework, what its implementation would look like, and the impact it would have on the Defense organization. Determine if aligning organizations, functions and processes in a general management framework could allow the Department to streamline--take work and layers out--create better linkage of strategy to outcomes, increase transparency and accountability, delegate authority and create an efficient delivery of capability to the joint warfighter in the near, mid and long term.

The CD initiative, if properly implemented, will contribute to the objective of this APC because a major purpose of CD is to ensure that new acquisition program starts are consistent with strategic priorities.

ACP 4—Process. This ACP also has a strong and explicit relationship with the CD process. There are two sub-parts. The first is to "Experiment with Conducting Trades in an *Integrated Capability Portfolio* Framework." (emphasis added)

> Statement of Expectation: An established methodology should be developed to facilitate trades and manage risk within and across a portfolio construct. Instantiation of the methodology must be capable of facilitating multiple management structures--centralized to federated.
>
> This action directs forming:
>
> …a team to experiment with the concept of Integrated Capability Portfolio (ICP) decision management and support methodologies [and] address what processes, incentives, activities and linkages are needed to manage cross portfolio and within portfolio trades in a hybrid enterprise that supports both Centralized and Federated management and accountability structures.

Action was assigned to USD(AT&L), PA&E and Joint Staff (no lead was designated) with a report to be presented to the DAWG in August 2007.

It is noteworthy that the term "integrated capability portfolio framework" is not precisely defined. The JCA Reassessment TOR (see Appendix D for reference) suggests the following definition: "Executive-level management of capability groupings that cover the entire DoD budget authority."

The second action item directly addresses the CD process (extracted in full):

Institutionalize the Department's Future Capability Investment Determination Process-Concept Decision

Statement of Expectation: In order to balance the Department's future capability development (DOTMLPF) it is necessary to put greater emphasis on early evaluation of solutions to meet capability needs in terms of their priority, affordability, timing and feasibility. This is needed to better guide decisions on where to invest and divest, and maintain balanced portfolios for near and far term strategic needs and resource constraints.

Institutionalize the concept decision process by examining the evaluation of solutions in terms of which Joint Capability Areas and strategic goals the solutions support, establishing criteria to measure process value, and identifying implementation needs.

- Action Lead: USD (AT&L)
- Supporting Organizations: JS/J-8, PA&E & Comptroller
- Timeline: Report progress, criteria to measure process value, and implementation needs to DAWG in June 2007 and December 2007 (Feedback in December should also include a recommendation on how best to institutionalize the concept decision process.)

This is reasonably consistent with current thinking on the CD process. One difference is the elevated role of the Comptroller, who has not been proposed for a strong role in the CD process. One question is what is meant by "establishing criteria to measure process value." Another is whether the USD(C) would have membership on the Tri-Chair (making it a quad-chair).

ACP 5—Strategic Resource Allocation. This ACP is concerned with the balance between investments in current versus future capabilities. It is suggested that separate fiscal guidance be issued for those two timeframes. USD(AT&L) and Comptroller are to co-lead a team to further examine this concept and provide recommendations. This ACP seems to be directed toward solving the age-old problem of using procurement to pay for exigencies arising in the operating accounts (O&M and MilPay). There is not a strong relationship with the CD process.

ACP 6—Performance Assessment and Feedback. This ACP addresses the need for an improved process for performance assessment, both internally and for external reporting under the Government Performance and Results Act. There is only a tangential relationship with the CD process.

Appendix D
THE FYDP-JCA MAPPING

As discussed in the main body of this paper, the Joint Capability Areas (JCAs) have recently been revised at the Tier 1-3 levels, and are still under development for lower levels. This appendix addresses the effort to map the Future Years Defense Program (FYDP) into the original JCAs as they existed before the recently-completed revisions. The Deputy Secretary of Defense asked the Director, Program Analysis and Evaluation (PA&E) to develop such a mapping. [1]

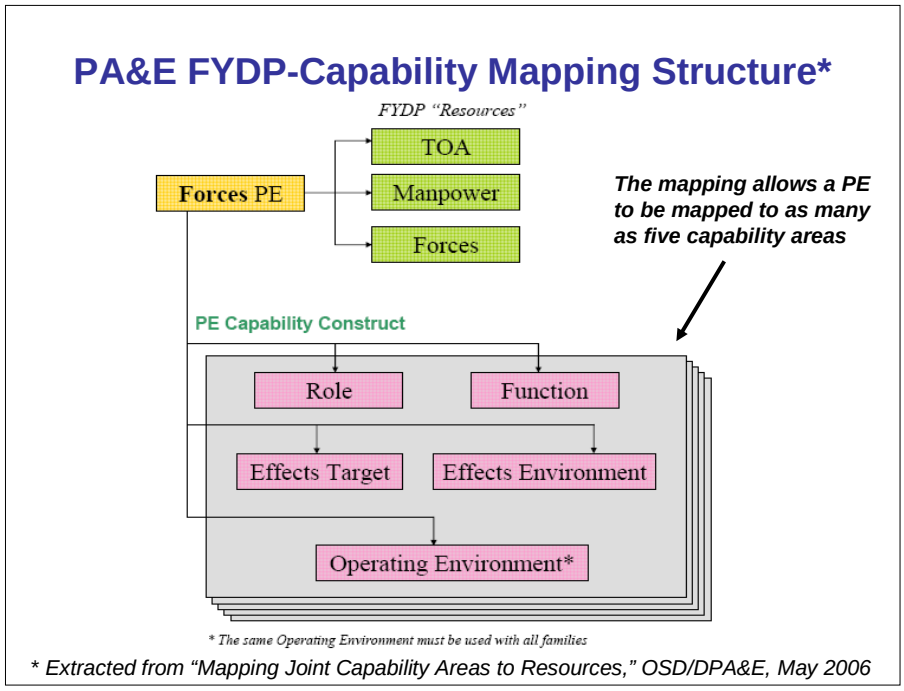

Figure D-1. The PA&E FYDP—Capability Mapping Structure

The methodology for the FDYP-JCA mapping is described in the paper referenced in the footnote, and the materials included here are, by and large, extracted from that document. Figure D-1 is an overview of the approach. By its nature, any such mapping is going to be very gross. For example, there might be highly important strategic objectives that are limited in the resources that can or need to be allocated to them. (An

[1] "Mapping Joint Capability Areas to Resources," Program Resources and Information Systems Management Division, Office of Program Analysis and Evaluation, May 2006.

example would be the strategic triad during the latter phases of the Cold War. Although it was very important, it didn't take a large percentage of the DoD budget to maintain an adequate capability.) On the other hand, relatively low priority activities in the strategic sense will consume substantial resources, because even though they are not a high strategic priority, practical considerations still require that they receive funding. Much of defense infrastructure falls into that category. For these reasons, one should approach a review of a JCA-FYDP mapping with modest expectations.

Another more practical consideration is that the FYDP program element (PE) structure evolved over many years to meet programmatic needs or other objectives. Unfortunately, some of this evolution has not been in the direction that improves the ability of the structure to provide insights into the programs being funded. Thus, there are numerous PEs that are basically "pots of money" that the DoD Components allocate as they deem appropriate, and visibility is not an objective. (There may be valid reasons for some of this obfuscation, for example, in the case of highly classified activities.)

The PA&E document referenced above described how the mapping was established. A brief overview is presented here. For those readers not familiar with it, it is necessary to describe how the FYDP data base is constructed.

Program Elements. The PE is the basic building block of the FYDP. The PE structure is specified by OSD(PA&E) for use by the Defense Components (Military Departments and Defense Agencies) in describing their future years program (budget year plus 6) to OSD. The Components are not required to use the OSD PE structure for their own programming. Typically, they have established a mapping of the financial structures they use internally into the OSD PEs for reporting purposes. This has the interesting result that inquiries with the Components as to the contents of a PE can be met with blank stares, since working level personnel are frequently not familiar with the mapping the Component uses (or even that there is one). The PE has a title and a description, but these frequently contain little or no detail of any help. An exception is the RDT&E PEs, because these are used for Congressional budget reporting. So, for those PEs excellent descriptive materials can normally be found. The PE code is made up of seven characters; an example is 0202114A, which is entitled "Light Divisions." The initial "02" specifies the FDYP "Major Force Program" (in this case, General Purpose Forces) and the last character specifies the Component—in this case Department of Army. All direct funding for the Army's light divisions is rolled up into this PE. There are separate records for TOA (Total Obligational Authority—the programmed dollars), manpower, and the number of units of this type that are programmed over the

FYDP. There is also a record created for each year of the FYDP. The PE funding is further broken down into Resource Identification Codes, which can be rolled up into budget appropriations. Thus, a complete unique record consists of five data elements: The FYDP position (which FYDP is it), the PE code, the RIC, the Fiscal Year, and the amount. In addition, there are mappings established into two other coding structures—the Defense Mission Categories (DMC) and the Force and Infrastructure Code (F&IC). As the name suggests, the DMCs assign each PE into a stratified mission category—the top level is the Major Force Program cited above. The F&IC is yet another assignment that maps the PEs into different force categories (e.g., operating, support) and infrastructure such as personnel, training, logistics, etc. (The referenced PA&E document provides more detail on these coding structures.)

Figure D-2. The Tier 1 Joint Capability Areas

The Joint Capability Areas. The JCAs were developed by the Joint Staff (J-7)[2] over the past several years, in response to the recommendation of the "Aldridge commission"[3] that the Department should move more rapidly in the direction of capability-based planning. In response, as part of the Operational Availability 05 Study, the Joint Staff developed the JCAs as a tiered decomposition of defense capabilities. When the PE-JCA mapping was defined, there were 22 Tier 1 capabilities (listed in Figure D-2 above) and 240 Tier 2 capabilities. It is clear from a cursory look at the original Tier 1 and Tier 2 JCAs that there was a large discrepancy between that construct

[2] See http://www.dtic.mil/futurejointwarfare/cap_areas.htm for the JCA Lexicon and related documents.

[3] "Joint Defense Capabilities Study: Improving DoD Strategic Planning, Resourcing and Execution to Satisfy Joint Capabilities," Honorable E.C. Aldridge, *et al* January 2004.

and the TOR-stated goal of an "Executive-level management of capability groupings that cover the entire DoD budget authority" and that are "mutually exclusive and collectively exhaustive for all DoD Capabilities."

The decomposition of the 22 Tier 1 JCAs into the 240 "capabilities" at the Tier 2 level resulted in numerous Tier 2 JCAs being included under more than one Tier 1 JCA. So if, for example, the Department were to resource by the 240 Tier 2 JCAs, they would not roll up cleanly into the Tier 1 JCAs. A cursory examination of the original Tier 1 JCAs indicates many interactions. For example, Battlespace Awareness and Command and Control have very substantial overlaps with all the operational JCAs, such as Land Operations, Maritime/Littoral Operations, and Air Operations.

The builders of the FYDP-JCA mapping overcame some of the limitations of the Tier 1 JCAs by bringing some Tier 2 JCAs up to the Tier 1 level and adding some categories needed for a meaningful mapping. Figure D-3 shows the way that was done. The result was an ability to view the resources along three dimensions—"roles, functions, and effects targets."

The utility of the JCA-FYDP mapping should be reassessed after it is revised for the new JCA structure. Ultimately, improvements in its usefulness will depend on a restructuring and expansion of the PE building blocks that would provide more fine-grained visibility into the DoD Components' programs and budgets.

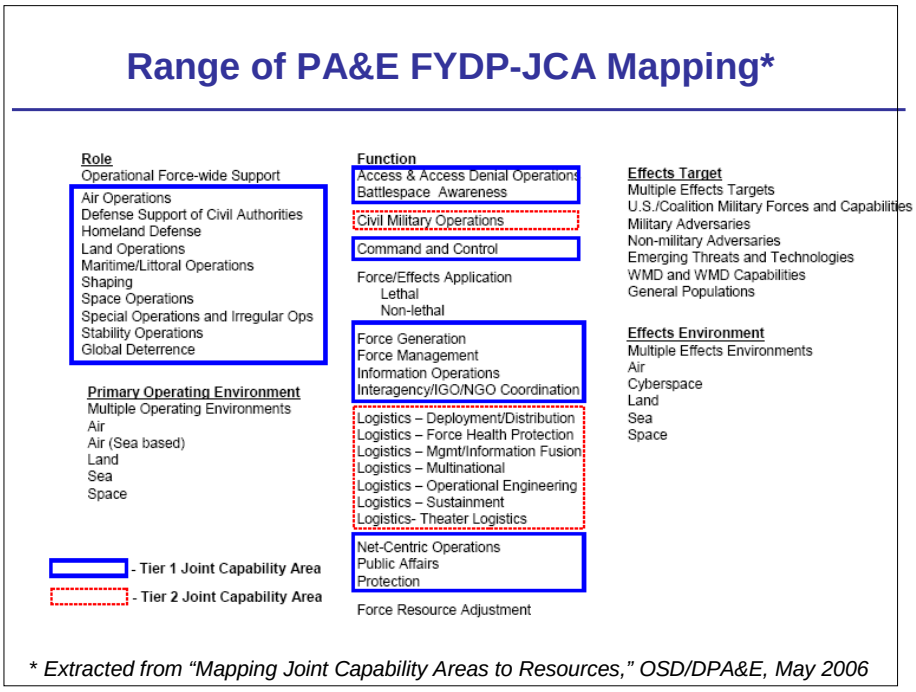

Figure D-3. The Range of the PA&E FYDP-JCA Mapping

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14. ABSTRACT

The primary purpose of the paper is to develop an approach to portfolio analysis in the Concept Decision (CD) process, which is an initiative from the 2006 Quadrennial Defense Review to improve the early stages of the defense acquisition process. The paper guides, in a general way, future practitioners in undertaking CD Evaluations of Alternatives (EoAs). The basic structure of such analyses is to identify zero-net-cost changes to the appropriate portfolio that would result in improved capabilities to meet specified challenges. The approach to portfolio analysis presented in this paper is as applicable to the tasks of the Institutional Reform and Governance (IR&G) Capabilities Portfolio Managers (CPMs) as they are to the tasks of the CD Evaluation of Alternatives study directors.

15. SUBJECT TERMS

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